Sky and TELESCOPE

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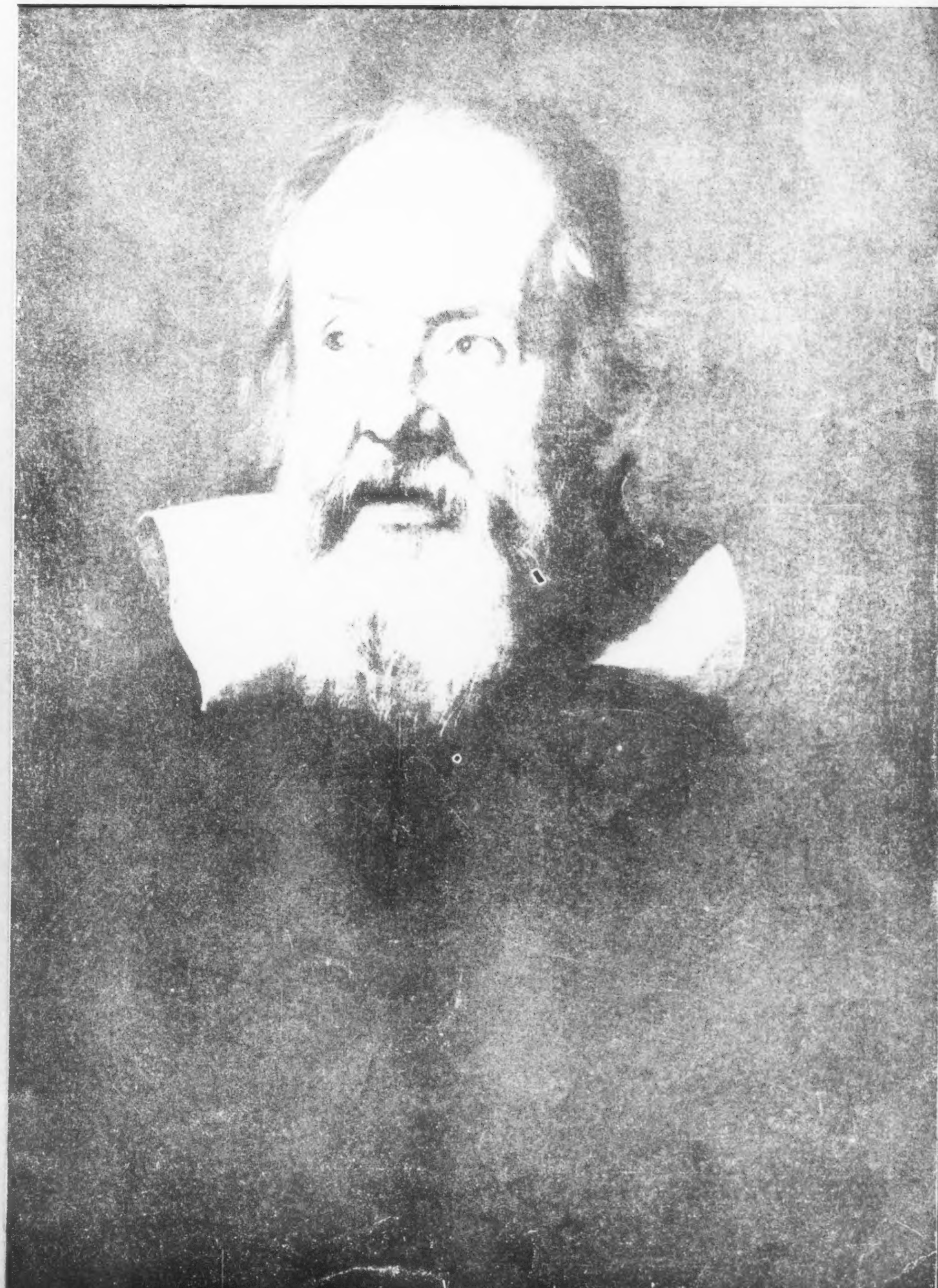

Galileo Galilei, by Sustermans

Sky and TELESCOPE

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CHARLES A. FEDERER, JR., *Editor*; HELEN S. FEDERER, *Managing Editor*

ENERGY IN THE SERVICE OF MAN

UNESCO plans annually to propose for worldwide discussion some theme with universal significance, to provide basic material for informal action. In 1949-50 the topic was "Food and the People." The second, for 1951, was "Energy in the Service of Man," on which a series of six articles published by UNESCO has just been received.

As might be expected, the present series is basically utilitarian, although the cultural aspects are evident in the first article, "Civilization and the Use of Energy," by Sir A. C. Egerton, Imperial College of Science and Technology, London. He briefly discusses the time-scale (age of the earth) and the history of man. There is frequent recognition of solar energy as the fundamental source for the maintenance of life (photosynthesis) and of its possibilities for heating and cooling houses and furnishing power supply.

Louis C. McCabe, of the U. S. Bureau of Mines, discussing "World Sources and Consumption of Energy," notes that the sun supplies some 2,000 times as much energy to the land areas of the United States as the country uses. He believes that when mineral fuels become critically short in supply, more efficient methods for consuming solar energy will be developed. At present, "Under the most favourable laboratory conditions, thermocouples will convert heat from the sun into electric current at about 5 percent efficiency, while the best commercial equipment will recover only 0.8 percent. In growing crops, the average recovery through photosynthesis is less than 0.1 percent but certain algae recover as much as 2 percent."

In "Energy in the Future," F. E. Simon, of Oxford, comments on current faith in nuclear energy (usually misnamed atomic energy). He reminds us that the automobile took 30 to 50 years of slow patient effort to develop, "and compared with the problems of nuclear energy the motor car is a comparatively simple device containing no fundamentally new ideas." He describes the sun as a "nuclear reactor which is enormously powerful, at a safe distance, and free for all." Assuming that 10 per cent of the solar radiation that gets to the surface of the earth can be utilized, he finds that an area the size of Egypt could supply the power requirements of the world at present.

The problem is how to collect this energy simply and cheaply. As solar radiation corresponds to high temperature it is mainly free energy, not heat. "The proper way of tapping it is not to use it as heat, but to find a process which will convert it directly into another form of free energy more useful to us." He suggests the industrialization of photosynthesis, but concedes many difficulties. Photocells might be used for direct conversion of solar energy into electrical current.

Professor Simon concludes that it will probably not be until the end of the century that either nuclear or solar energy will be able to take over from chemical fuels, although workable installations of both types should be producing power in from 10 to 20 years time.

The other three papers in the series are: "Utilization of Energy," Gustav Eichelberg, Swiss Federal Polytechnic School; "Energy in Its International Aspects," Pierre Ailleret, French National School of Roads and Bridges; "The Role of Energy in Under-developed Areas," M. S. Thacker, Indian Institute of Science. Presumably copies of all these papers and a bibliography (February 25, 1952) of British publications on the subject may be obtained from Professor Pierre Auger, director, Natural Sciences Department, UNESCO, Paris, France.

D. H.

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COVER: A photograph of the portrait of Galileo in the Uffizi Gallery at Florence, Italy, by Giusto Sustermans (1597-1681). He was a Flemish painter (Van Dyck school) who came to the Medicean court as a young man, where he became court painter to Cosimo de'Medici II. Absolute fidelity to physiognomy was his characteristic. (See page 211.)

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BACK COVER: Antares and the head of the Scorpion appear in this Milky Way photograph by Frank E. Ross made at Lowell Observatory. The three bright stars in the Scorpion's head are in the upper right part of the field; Sigma Scorpii is just above the center, and the large globular cluster M4 is to the left of center; Antares is farther to the left. The brightest and largest nebulosity surrounds the star Rho Ophiuchi, upper center. The exposure time was three hours, using a Ross-Fecker lens of 5-inch aperture, 35-inch focus. The engraving shows a portion of Plate 2 of the Ross-Calvert "Atlas of the Northern Milky Way," University of Chicago Press, 1934.

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The Quirinal Hill, known also as Monte Cavallo, is the highest of Rome's seven hills, from which there is a fine open view of the city. The Giardino di Monte Cavallo was probably here, where it may well be that Galileo demonstrated his telescope in 1611 when he visited the villa of Cardinal Bandini. Palazzo Quirinale, started in 1574, was used as a summer residence by the popes from then until 1870; it was here that Pope Urban VIII gave orders for Galileo to recant, during the latter's sixth visit to Rome. The principal door, with statues of St. Peter and St. Paul on the loggia base, was executed by Bernini, and the tower on the left was added by Urban VIII. The statues in the square are of Castor and Pollux and their horses.

GALILEO'S VISITS TO ROME - I

BY WALTER J. MILLER, S.J., *Vatican Observatory*

GALILEO'S first visit to Rome took place in the year 1587. At the age of 23, he already aspired to a vacant professorship of mathematics in Bologna, and for this purpose he needed the support of influential people and the recommendation of eminent mathematicians. One of those whom Galileo then visited in Rome, and who became his lifelong friend and correspondent thereafter, was the Jesuit Father Christopher Clavius, professor of mathematics at the Roman College almost uninterruptedly for 47 years. Clavius was known as the Euclid of the 16th century, and co-operated with Pope Gregory XIII in establishing the Gregorian calendar. Shortly after this 1587 visit, Galileo wrote from Florence to Father Clavius to ask his advice about the proof of a theorem concerning the center of gravity of solids. This autograph letter, the earliest extant letter of Galileo, is now in the archives of the Pontifical Gregorian University, successor to the Roman College when the latter was appropriated in 1873 by the Italian government during the unification of Italy.

Galileo's second (and happiest) visit to Rome was from March 29 to June 4, 1611. He was triumphantly received as the man of the hour. It is easy to see why. Galileo's discoveries in the field of mechanics could be understood only by the learned few, but his astounding telescopic discoveries could be understood by all alike, even though their real significance would not be fully grasped or commonly accepted for generations to come.

Galileo had first pointed his telescope at the skies in the late months of 1609, and sensational discoveries had been made and announced in rapid succession during 1610: mountains and craters on the moon, star clouds in the Milky Way resolved into immense numbers of stars quite different from the planets, four moons of Jupiter, the phases of Venus, the peculiar and puzzling egg shape of Saturn, and finally sunspots. All except the last were explicitly confirmed in detail from their own observations by the Jesuit astronomers of the Roman College, at a solemn academy held in Galileo's presence and in his honor in May of 1611. This must have been the high point of his visit to Rome, for at least three cardinals were present, along with many high ecclesiastics, theologians, scientists, and other eminent personages of Rome. To lend credence to the unprecedented discoveries, the

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This article is based on an idea evolved by Rufus Suter, Washington, D. C., author of "Galileo in Padua," *Sky and Telescope*, November, 1951. —ED.

telescope used by Father Clavius and his Jesuit collaborators to make the confirmatory observations was on public display.

On this occasion, the Latin word *perspicillum* was still used for the word telescope, although the new word *telescopium* had already been coined by Giovanni Demisiani and used in Rome by Federico Cesi, Marchese di Monticelli, at his banquet in Galileo's honor on April 14, 1611. Galileo was greatly pleased when Cesi enrolled him as the sixth member of his eight-year-old Accademia dei Lincei, on April 25th; and the Lincean album containing his signature on that occasion is still preserved at the modern home of this celebrated academy in Palazzo Corsini, No. 10 Via della Lungara. Thereafter, Galileo faithfully complied with the academy's rule that members must use the title of Linceo in their scientific publications, and he more than complied with the academy's ideal of studying the facts of nature with the close scrutiny of a lynx. Palazzo Cesi, where Galileo was entertained and honored, is located at No. 21 Via della Maschera d'Oro. An inscription on the facade commemorates the event, but the palace itself is now the seat of the Tribunale Supremo Militare of Rome.

The Palazzo Firenze, where Galileo was a guest during his second visit to Rome, in 1611, as it looked on May 14, 1952. The building is now No. 27 Piazza Firenze. Photograph by the author.

Another feature of Galileo's 1611 stay in Rome was the triumphant demonstration of his telescope and its wonders, in the Giardino di Monte Cavallo (on the Quirinal Hill) at the residence of the Florentine Cardinal Ottavio Bandini. Among the many dignitaries present were Cardinals Bandini and Lorenzo Bianchetti, to whom Galileo also showed spots on the sun. At a dinner given in his honor by the Duca di Acquasparta (father of Federico Cesi), at his villa above San Pancrazio on the Janiculum Hill, Galileo once astounded the distinguished guests by showing them first the moons of Jupiter and then letting them read the inscription of Sixtus V above the Loggia delle Benedizioni at the Lateran Palace, over three miles away. Galileo displayed the moon and Venus through his telescope, to the Jesuit Cardinal Robert Bellarmine and to many others. Galileo's letter of April 22, 1611, to his Florentine friend, Filippo Salviati, reports that various prelates and princes had been just as much impressed by looking at celestial objects through his telescope as he himself had been in viewing all their marvelous statues, paintings, room decorations, palaces, and gardens — so we know that Galileo did his full share of tourist sightseeing in Rome.

The same letter also tells about the very cordial audience he had had that very morning with Pope Paul V (Camillo Borghese). Galileo was introduced to the Pope by the Tuscan ambassador to the Holy See, Giovanni Niccolini, at whose residence (in Palazzo Firenze, still existing today at No. 27 Piazza Firenze) Galileo was then staying in virtue of his new (June 10, 1610) official position as court philosopher and mathematician of Cosimo de'Medici II, grand duke of Tuscany. Writing to the latter on May 31st, Cardinal Francesco Maria dal Monte says that Galileo's visit had given such great satisfaction to all that, if they were living in the times of the ancient Roman republic, they would surely have erected a statue on the Capitoline Hill to honor him for his genius and his remarkable discoveries.

Galileo had long since been convinced of the truth of the Copernican doctrine that the earth rotates daily on its axis and revolves annually about the sun. In 1596 his astronomer friend, the celebrated Johannes Kepler, had had a work, *Prodromus Dissertationum Cosmographicarum,* condemned as heretical by the Protestant theological faculty of Tübingen, for its advocacy of the "antiscriptural" Copernican theory. On August 4th of the following year, Galileo wrote to Kepler, saying that he himself had embraced the opinion of Copernicus many years ago, after having used the theory to explain many natural effects that were inexplicable by the commonly prevailing Ptolemaic hypothesis. He had never dared to publish either his researches or his refutation of adversaries, being "afraid of the lot of Copernicus, our teacher, who, although he did acquire immortal fame with some few, yet with an infinite number of people (for such is the number of the stupid) he came forth only to be laughed at and hissed off the stage."

If Galileo had already convinced himself of the truth of the Copernican theory many years before 1597, surely we may imagine how the discoveries he made in 1610 and the enthusiastic reception he received in Rome in 1611 encouraged him thereafter to become the fearless and even reckless public champion of Copernicanism. Today it is clear that never in his lifetime did Galileo possess a really valid proof of this theory, and the proof from the ebb and flow of the tides on which he laid so much stress was even completely false. But his penetrating intuition immediately realized the full significance of the phenomena his telescope enabled him to observe, and he impetuously set out to show everybody, willy-nilly, that the Ptolemaic interpretation of the facts was false.

It is important to try to understand why Galileo's opponents were so obstinately conservative. It was not only that the Ptolemaic theory had been taught as incontrovertible fact for centuries past by both scientists and philosophers. It was not only that ordinary everyday people were convinced from the evidence seen by their own eyes that the sun did move daily from east to west and yearly through the signs of the zodiac. But also and much more, it was due to the fact that in those days both Protestants and Catholics alike considered the Bible to be the supreme authority not only in theology but also in science.

For instance, take the famous initial text in *Ecclesiastes* (the Preacher) where Solomon, after summing up life with the words, "Vanity of vanities, and all is vanity," goes on to say: "One generation passeth away, and another generation cometh; but the earth standeth forever. The sun riseth, and goeth down, and returneth to his place; and there rising again, maketh his round by the south, and turneth again to the north." That text, taken literally, could mean only that the sun and not the earth did the moving.

In the absence of valid proof to the contrary, lay people and theologians alike in those days suspected as heretical any new and revolutionary doctrine which would interpret such texts in a way that contradicted the obvious and literal sense of the words. There was no question of being inimical or un-

friendly to science; to the mind steeped in the traditional interpretation of Scripture and not yet converted from the authority of Aristotle to the modern method of scientific observation, it seemed that the Copernican doctrine was radically false and unscientific, precisely because it appeared antiscriptural and therefore heretical.

Galileo correctly answered (in the very words suggested to him by Cardinal Cesare Baronio) that Holy Writ is intended to teach men how to go to Heaven and not how the heavens go. In other words, the Bible is not a book of astronomy, nor does it aim to teach science, and in speaking of celestial phenomena it uses current expressions which would be intelligible to ordinary people thinking and speaking according to the obvious appearances of things; and these expressions are not intended to explain the phenomena or to state anything about the true structure of the heavens.

Galileo's third visit to Rome was from December 11, 1615, until June 1, 1616. The reason for the visit was Galileo's desire to defend on the spot his views on the relation between faith and science. On December 21, 1613, he had written a letter to his former pupil of Padua, the Benedictine Father Benedetto Castelli, and in 1615 he wrote an even longer letter (running to 40 printed pages in the 20-volume *Edizione Nazionale* of Galileo's works) to the dowager grand duchess of Tuscany, Cristina di Lorena; in both letters he brilliantly explained how the disputed passages of Scripture were to be reconciled with Copernicanism.

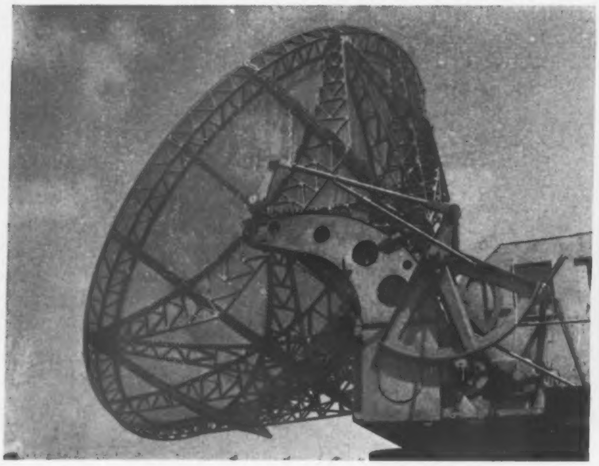
These and other such letters of Galileo were often recopied and widely circulated, and the Dominican Fathers of Florence had asked Cardinal Paolo Sfondrati, the prefect of the Roman Congregation of the Index, to investigate the orthodoxy of the letters. However, since the letters had not been printed, the question was turned over to Cardinal Giovanni Millini, the secretary of the Holy Office or Inquisition, whose function it was to guard the faithful from danger of false doctrines. The mild and informal decision was that a few passages which at first sight seemed objectionable could be taken in a good sense, and that on the whole there was no divergence from Catholic doctrine. Unfortunately, Galileo was not content with this negative vindication. His friends advised and implored him to avoid theology and to confine himself to mathematics and physics ("Write freely but be careful to keep outside the sacristy!"). They begged him to be satisfied with teaching Copernicanism as a hypothesis, but he insisted on teaching it as a proved fact. Orally and in writing he campaigned actively, in private and in public, before eminent personages in ecclesiastical and lay circles in Rome, for a winner-take-all decision.

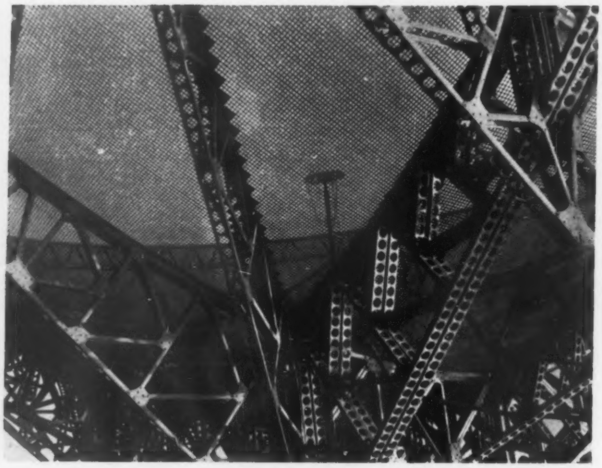
The discussion thus seemed no longer personal but rather doctrinal in nature, and Galileo's many enemies could urge to the Holy Office the necessity of removing once and for all the uncertainty concerning the relations between Copernicanism and Christian tradition. Galileo's 1613 book on sunspots (which was published in Rome by the Accademia dei Lincei with papal imprimatur from the master of the Sacred Palace) contained passages openly teaching Copernicanism as a fact, and so it was

(Continued on page 221)

Left: Galileo was entertained many times at the Roman College by Clavius and other Jesuit astronomers. Built in 1585 by Ammannati, the building was taken over in 1873 by the Italian government, although Father Angelo Secchi's observatory continued active until his death in 1878.

Right: On the Piazza della Minerva stands the church of Santa Maria sopra Minerva, built over the ancient temple to Minerva Calcidica. The doorway at the left, No. 42 Piazza della Minerva, is the entrance to the Dominican Convent where sessions of the Holy Office or Inquisition were held. The obelisk is 6th century B. C. Egyptian, and the monument of the elephant is by Bernini (1667). The Pantheon is 200 feet away in the direction of the obelisk shadow.





The radio telescope at Kootwijk, Holland, has a parabolic receiver about 25 feet in diameter. At the right, a closeup shows the wire mesh, the dipole at the focus, and the supporting structure. Philips Company photograph.

Galactic Exploration by Radio

BY OTTO STRUVE, *Leuschner Observatory, University of California*

THE PAST 25 years have witnessed the most spectacular development of science in history. Discoveries of undreamed-of importance have succeeded one another at such a rapid rate than even in the field of an astrophysicist's specialization it is difficult to keep track of them.

Nearly three years ago I reviewed in this journal the exciting new science of radio astronomy. Progress since then has been unbelievably rapid. New radio telescopes have been built, dozens of new discrete radio sources have been discovered, and accurate observations of the sun and its flares in radio frequencies (*Sky and Telescope,* March, 1952) have superseded the haphazard trials of the pioneers. There are indications that what we have designated as radio stars are not stars at all, but are really diffuse nebulae of a kind that is related to the Crab nebula. But perhaps the most exciting new result in radio astronomy was the discovery, in the spring and summer of 1951, of a strong interstellar glow at a wave length of 21 centimeters, or a frequency of 1,420 megacycles per second (*Sky and Telescope,* August, 1951, page 237). In the hands of the students of galactic structure, this discovery has already revolutionized our thinking concerning the Milky Way, and it promises even more remarkable results in the near future.

First we must consider just what it is that produces this invisible glow. Twenty-five years ago, no one bothered about radiations that lie much outside the visible region of the spectrum. We knew, of course, that the work of Hertz had shown that an alternating electric current, in the form of a spark, for example, could produce at a considerable distance another spark in an otherwise unactivated loop of wire, with a small gap between the ends of the wire. But astronomers felt secure from these complications in the field of experimental physics. Even as recently as 10 or 15 years ago, no astronomer would have believed that he would one day become concerned with the hyperfine structure of the hydrogen atom. But that is exactly what we shall discuss this month.

The hydrogen atom consists of two particles — a nucleus, called the proton, and a single electron. In the picturesque, but unfortunately inaccurate, representation by Bohr we may think of the electron as revolving around the proton, the force between them being the electrical attraction between the positive charge of the proton and the negative charge of the electron.

Ordinarily the electron can move only in certain distinct orbits, and cannot occupy any randomly selected intermediate orbits. Also it can "jump" from one orbit to another. If it is in its innermost orbit it can jump only to a more distended orbit, and in doing so it absorbs a quantum of energy. After having reached the new orbit, it remains there for about 10^{-8} second and then "falls" back to one of the smaller orbits, sometimes even "cascading" from one to the next, until it is again located in the first, or innermost orbit. Every such downward jump is accompanied by the release, or emission, of an appropriate quantum of light.

If the jump is a large one, that is, from a greatly extended orbit to one of very small dimensions, the quantum is ultraviolet in color; if the jump is between orbits of nearly the same dimensions, the quantum is red or infrared, or may have a wave length so great that we would place it in the microwave or radio region of the spectrum.

It has been known for many years that what the early physicists regarded as single orbits are really groups of orbits, all of very similar dimensions. In order to distinguish these groups, the words *fine structure* were used to describe their close proximity, as contrasted to the wide intervals that separate each fine-structure group from the next. The theoretical work of some of the greatest physicists, for instance, A. Sommerfeld in Munich, gave a plausible physical explanation of the fine-structure groups.

More recently, physicists have found that the structure of the electronic orbits is still more complicated; they possess a ***hyperfine structure*** in addition to the ordinary fine structure. In consequence of this hyperfine structure, the innermost electronic orbit of hydrogen (which possesses no fine structure) consists of two orbits that are very close together. Ordinarily we cannot distinguish between them, and when we speak of neutral hydrogen atoms in the ground state we usually lump together those that are in the two hyperfine-structure orbits. Yet, I. I. Rabi and his associates at Columbia University have succeeded in devising laboratory experiments that permitted them to distinguish between the atoms in the lower and the higher of the two levels.

Because the separation between these two orbits is very slight, the jump of an electron from one to the other absorbs or emits a quantum of "radio light"

whose wave length is 21 centimeters. Contrast this with the wave lengths of visible light, which are of the order of 1/20,000 centimeter.

Until 1944 no one expected that such jumps could really take place. Many of the jumps between different orbits of an atom are "forbidden" by the rules of quantum theory. The 21-cm. wavelength jump was most probably forbidden by these same rules, and would not occur under normal conditions. Still, astronomers know that some of the forbidden jumps are not completely impossible. The "forbiddenness" is a relative property of the atom. Exceptions to the rule are possible, and forbidden jumps are really very rare transitions that do not occur in the laboratory because various events, such as collisions with the walls of the experimental container, disturb the atom before it has time to make the forbidden jump.

In a normal state or orbit, as we have already seen, the electron remains only one one-hundred millionth of a second before it proceeds to make a permitted jump. In the upper of the two hyperfine structure levels of hydrogen, it remains for 11 million years! In the laboratory too many other things can happen to the electron before the 11 million years have elapsed. But in interstellar space, an atom may well remain undisturbed for very long periods. The electron then has plenty of time to make up its mind (or whatever it is that makes an electron decide to jump) to return to the ground orbit.

This was first recognized by the young Dutch astrophysicist, H. C. van de Hulst, and presented by him in a colloquium at Leiden. The idea was published in a relatively little-known periodical (*Ned. Tijdschrift voor Natuurkunde, 11*, 210, 1945), and it did not seriously come to the attention of astronomers until March 25, 1951, when H. I. Ewen and E. M. Purcell, of Harvard University, found a strong radiation of 21-cm. wave length from the Milky Way. Their horn-type antenna is pictured on this page. A few weeks later even more complete results were announced from the Dutch radio observatory at Kootwijk, by C. A. Muller and J. H. Oort. In July of last year, these results were confirmed by W. N. Christiansen and J. V. Hindman in Australia.

It should be realized that the Milky Way emits a general, continuous glow in all radio wave lengths. This glow can be regarded as the emission of radiation, from nebulae and also from disturbed areas on stars, that is comparable to the continuous white light of the sun, and represents an extension of it into the radio region of the spectrum.

The hydrogen radiation at 21 centimeters is a superposed emission, similar to the emission lines produced by the

H. I. Ewen adjusts the pyramidal horn antenna with which he first detected 21-cm. radiation from the Milky Way. The horn, on the fourth floor of Harvard's Lyman Laboratory, was fixed in position and pointed south at a declination of −5 degrees.

visible glow of the Orion nebula. If a radio receiver is tuned exactly to the 21-cm. wave length, it records radiation from the continuous sources and also from the emission line. But if it is tuned to 20 or to 22 centimeters, it records only the continuous radiation.

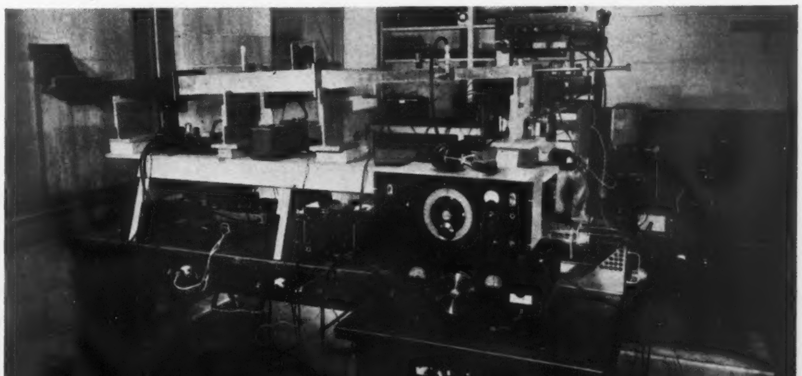
The observational and theoretical results are now sufficiently complete for a preliminary discussion. The photos on the facing page show the Kootwijk radio telescope. Its aperture is 7½ meters, and its focal length is 1.7 meters. The wire mesh is so fine that all "fish" in the form of radio waves longer than a few centimeters are caught and reflected toward the dipole receiver at the focus of the parabola. The amplifiers, recorders, and the like are located in the cabin behind the large reflector.

The project is a co-operative enterprise of the Dutch observatories, the Philips Company, makers of electrical lamps and equipment, and the Dutch post and telegraph service. In this country we are used to finding scientific interest among commercial firms, but who would expect the postmaster general to have an interest in a radio telescope?

The resolving power of this first instrument is not very great, about 2.8 degrees, but the Milky Way as seen by our eyes is much broader than this. Hence, even this resolving power is sufficient to disclose the broader structural features of the galaxy. A much larger radio receiver, 25 meters in aperture, is now under construction in Holland.

Ordinarily, the radio telescope is fixed at a given declination, in the meridian, and the earth's rotation causes the sky to sweep across the 2.8-degree cone of reception. The resulting effect is recorded automatically on strips of paper. The preliminary observations have shown a great width of the galaxy as an emitter of 21-cm. radiation, especially in the direction of the galactic center (top of Fig. 1). For instance, at the celestial equator, the width of the Milky Way band from which emission is recorded is some 30 degrees wide, whereas in this region the visible Milky Way is less than half as wide.

This is rather remarkable, because



A view of Dr. Ewen's equipment set up for the 21-cm. experiments. The wave guide connecting to the horn shown above comes in the window at the left.

the distribution of the ordinary photographic hydrogen glow, produced by Balmer jumps of interstellar atoms, is very greatly concentrated toward the central line of the Milky Way — if anything, it appears narrower than the starry band we see with our eyes. The explanation must be either that the ground-level hydrogen is distributed in a very different manner from the Balmer-jump hydrogen, or that we cannot see very deeply into the interstellar hydrogen mass when we tune our instruments to 21 centimeters.

The first explanation is not very reasonable. The Balmer jumps are produced by hydrogen atoms that spend most of their lives as ground-level atoms; there is no intrinsic difference between the two. A ground-level atom becomes excited or ionized when it is struck by a quantum of light from a distant star. It then produces a series of cascading jumps, emitting the Balmer lines which we can photograph. Finally, after a very small fraction of a second, it returns to one of the two hyperfine-structure levels of the ground state, and it remains there for many years. Hence, the distribution of the hydrogen atoms should not be greatly different in space. Only when the hydrogen atoms happen to be near very hot stars are they more often excited and ionized than would otherwise be the case. The photographically intense nebulosities are always located in the vicinity of such stars.

The second explanation is undoubtedly the correct one. Suppose that our radio instruments cannot penetrate very deeply into the Milky Way; then its width will appear great. The effect is the same as when you drive along a dusty road at night. When the dust is very thick, your headlights illuminate the murky mass close to your car and the diffusely illuminated band is broad. But when the dust is thinly distributed, the illumination extends all the length of the road and the band is narrow.

In the light of the Balmer lines of interstellar hydrogen, when on the average only one out of 10^{19} atoms participates in the emission, we can see to great distances, our vision being obstructed only by intervening dark clouds of cosmic dust or smoke. But, as with thick dust over a roadway, so many atoms take part in the 21-cm. radiation that the medium becomes opaque, or self-absorbing, at a relatively short distance.

The most recent determination of the width of the Milky Way in hydrogen 21-cm. radiation is by Christiansen, as shown in Fig. 2. The maximum falls in the direction of the galactic center, but the distance to which we can penetrate is, according to a recent paper by J. P. Wild (*Astrophysical Journal*, March, 1952), only 1,000 light-years, while the center itself is known to be

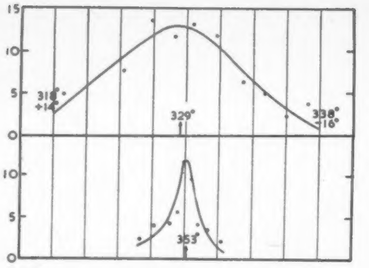


Fig. 1. The intensity of 21-cm. radiation from Dutch observations. Intensity is the vertical scale; time runs horizontally at 20-minute intervals. The upper scan is toward the galactic center. The lower scan is nearly along the line ZA of Fig. 4, as described in the text.

from 25,000 to 30,000 light-years away.

Therefore, it would seem that the new radio method permits us to explore only the nearer portions of the Milky Way galaxy, despite the fact that the dust clouds (which are serious obstacles to explorations in visible light) present no obstacle to the long waves of radio. These waves bend around the grains of cosmic dust as they do around snow crystals in the atmosphere of the earth. The dark nebulae of the famous Milky Way photographs by Barnard and by Ross do not exist in the domain of radio astronomy! Nor do terrestrial clouds, or even daylight, interfere with the observations. The radio astronomer can work as well in cloudy Europe as he can on the clearest mountaintop. The only interference he tries to escape comes from man-made electrical disturbances; most of these can be avoided by shielding the instruments behind metal screens.

There is, however, another factor that makes it possible to use 21-cm. observations for analysis of the structure of the galaxy. This factor is the Doppler effect of the differential rotation of the galaxy, and the remainder of this article briefly discusses the method of observation involved.

Just as in the case of optical spectral lines, the radio line at 21 centimeters is not infinitely narrow. The width of the line can be found when the radio receiver is gradually tuned off the true frequency of about 1,420 megacycles per second. This effect of *broadening* of the line (which is not to be confused with the width of the Milky Way) is caused by the irregular motions of the hydrogen atoms in interstellar space, of which the line-of-sight components are ±5 kilometers per second. These motions cause innumerable little Doppler displacements which are determined by the famous relation:

$$\frac{\text{Change of wave length}}{\text{Wave length}} = \frac{\text{Velocity of atoms}}{\text{Velocity of light}}.$$

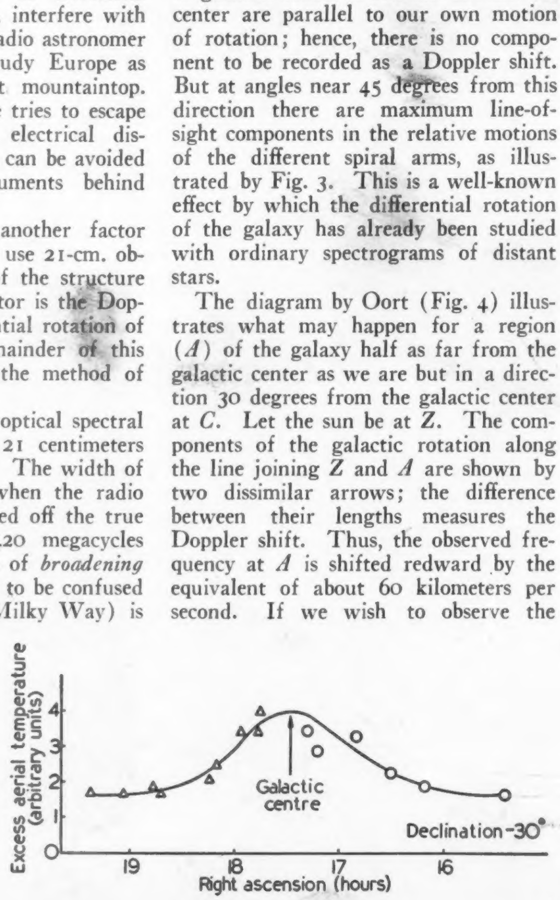
In our case the wave length is about 21 centimeters. The ratio on the right side is 5/300,000. Thus, an average atom tunes in at a wave length that may be short or long about 0.0003 centimeter. Can we tune the radio receiver with sufficient precision to recognize this small difference? It appears that we can.

The foregoing paragraph describes the application of the Doppler factor to the broadening of the 21-cm. line resulting from random motions of the emitting hydrogen atoms. The actual probing of the galaxy, however, is accomplished because there is an additional Doppler effect that depends on the distance of the emitting atoms when we observe them in certain directions.

The Doppler shift can reveal only motions of approach or recession. When we look toward or away from the galactic center, all the relative motions of galactic bodies in rotation around the center are parallel to our own motion of rotation; hence, there is no component to be recorded as a Doppler shift. But at angles near 45 degrees from this direction there are maximum line-of-sight components in the relative motions of the different spiral arms, as illustrated by Fig. 3. This is a well-known effect by which the differential rotation of the galaxy has already been studied with ordinary spectrograms of distant stars.

The diagram by Oort (Fig. 4) illustrates what may happen for a region (A) of the galaxy half as far from the galactic center as we are but in a direction 30 degrees from the galactic center at C. Let the sun be at Z. The components of the galactic rotation along the line joining Z and A are shown by two dissimilar arrows; the difference between their lengths measures the Doppler shift. Thus, the observed frequency at A is shifted redward by the equivalent of about 60 kilometers per second. If we wish to observe the

Fig. 2. The variation of 21-cm. radiation along declination —30°, observed by W. N. Christiansen (unpublished). The triangles are for directions south of the galactic plane, the circles for points north of it. From the "Astrophysical Journal."



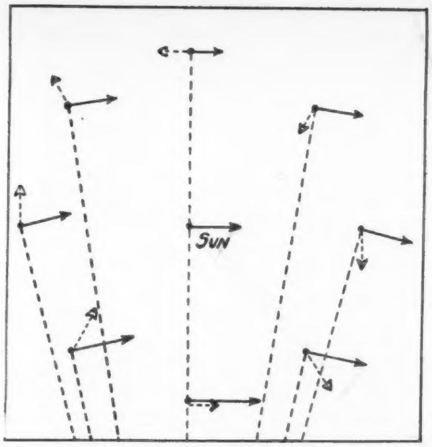


Fig. 3. As a result of galactic rotation, shown by the solid arrows, regions of the galaxy in various directions have motions relative to the sun shown roughly by the open arrows. The galactic center is toward the bottom of the page.

ground-level hydrogen located at *A*, about 8.7 kiloparsecs from the sun, we must tune in, not at 21 centimeters, but at a longer wave length.

The lower part of Fig. 4 shows how the relative Doppler displacement changes along the line *ZA*, and beyond to a point 17 kiloparsecs distant and about as far from the center of the galaxy as we are. Thus, by a proper choice of wave length, we can select any region along this line of sight for analysis in 21-cm. radiation.

If we should gradually change the tuning of our receiver from 21 centimeters longward, we would at first detect radiation that comes from nearby, where the galactic rotation is sensibly the same as that of the sun. Then we would gradually record more and more distant regions. As we would do so, the width of the Milky Way as observed by this radio energy would become progressively narrower; finally, it would become so narrow that it would subtend less than the 2.8-degree angle of the antenna receiver and the recorded intensity would decrease.

The actual observations must be made with a narrow and fixed tuning at any one sweep of the sky. The preliminary sweeps of Fig. 1 may now be compared. The upper half is very broad and indicates that the observations do not extend very far in the direction of the galactic center. The lower half shows the result of a sweep for a tuning at a wave length considerably greater than the normal value and in a direction corresponding to that of region *A* in Fig. 4. The apparent width of the Milky Way is now quite small — it crossed the antenna meridian in less than an hour — as Oort and Muller had predicted for distances of the order of 30,000 light-years. According to recent information from Dr. Oort, the observations by Muller now extend to about that distance, but soon he should be able to penetrate clear through our Milky Way spiral.

Thus, by simply tuning in upon a wave length that corresponds to a known value of the galactic rotation effect, we can render invisible the nearer clouds of hydrogen and examine those clouds that lie at a tremendous distance from us. If, for example, there should be a large cloud of neutral hydrogen at point *A* of Fig. 4, the sweep of the sky made with the proper tuning would reveal an abnormally high maximum of intensity in the curve corresponding to the lower part of Fig. 1. No such peak intensity would be observed with a slightly different tuning, but tunings for substantially different distances would have peaks of intensity indicating other hydrogen clouds where they exist.

In galactic longitude 50°, that is, roughly in the direction of Cygnus, Muller has found inside the broad hydrogen emission belt (which must correspond to Morgan's nearby spiral arm, described in *Sky and Telescope* for May, 1952) two other hydrogen condensations which appear to approach us (or we them) with velocities of 60 and 90 kilometers per second, respectively. Oort concludes that these concentrations may correspond to spiral arms at distances of 20,000 and 30,000 light-years, well outside of the nearby arm.

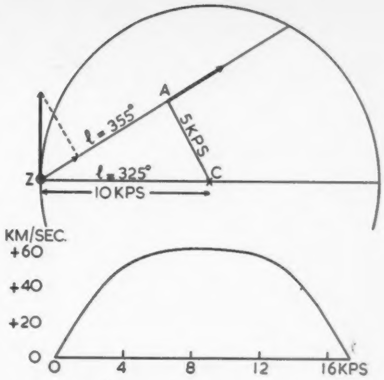


Fig. 4. The net Doppler effect in a direction 30° from the galactic center.

The radio observations confirm the great abundance of hydrogen in interstellar space, on the average about one atom for every two cubic centimeters. The vast majority of these atoms are concentrated in diffuse clouds which may be 10 times as dense as the space average. Not self-luminous in visible light (except where close to hot stars), these clouds shine only in the 21-cm. wave length and have a temperature of about 35° absolute, in good agreement with a theoretical determination by L. Spitzer, Jr. Following B. Stroemgren, we designate these gaseous clouds as H I regions, while the Balmer-emission clouds are called H II regions.

Notes on the IAU Meeting in Rome

The International Astronomical Union, meeting for its eighth general assembly in Rome, Italy, will convene on the morning of September 4th, and adjourn on the 13th, according to information received concerning the tentative program. The hosts are the Italian scientists, especially the astronomers, of the Italian national research council, the Consiglio Nazionale delle Ricerche, and sessions will be held at its headquarters and at the Faculty of Physics and Mathematics at the nearby University City (Citta Universitaria). The inaugural ceremony will be in the Palazzo dei Conservatori, Campidoglio, in the presence of the president of the Italian Republic.

Symposia on stellar evolution, astronomical instrumentation, and the astrometry of faint stars, will be held during the assembly. The program for these days also tentatively includes a number of visits to places of astronomical interest: to the Vatican Observatory at Castel Gandolfo, where there will be a group audience with His Holiness Pope Pius XII; to the national computation center (the Istituto Nazionale di Calcolo); to the museum and observatory of Monte Mario. Following the assembly, excursions are planned to L'Aquila degli Abruzzi and the nearby Gran Sasso branch of the Monte Mario Observatory at Campo Imperatore (see *Sky and Telescope,* September, 1951), and to Padua and its branch observatory at Asiago, in the foothills of the Dolomites.

From September 14th to 19th, following the IAU meetings, there will be a special series of meetings organized by the Accademia dei Lincei on problems of solar physics, with a number of invited papers. These will be held first at the academy's headquarters in Rome, and for the last three days in Florence at the Arcetri Astrophysical Observatory. All astronomers are invited to attend these meetings.

The committee on arrangements for the IAU meeting is under the direction of Prof. Lucio Gialanella, vice-director of the Monte Mario Observatory, who is secretary-general for the executive committee of the meeting. He may be reached at the Consiglio Nazionale delle Ricerche, Piazzale delle Scienze, n. 7, Roma, Italia. In the United States, information may be obtained from Dr. J. J. Nassau, Warner and Swasey Observatory, East Cleveland, Ohio, who is chairman of the United States national committee of the IAU.

NEWS NOTES

By Dorrit Hoffleit

TECHNETIUM IN THE STARS

Technetium, element 43, originally discovered in nuclear experiments and then identified on the sun (*Sky and Telescope,* September, 1951, page 272), has now been found in some unusual stars. At the National Academy of Sciences meeting in April, Dr. Paul W. Merrill, of Mount Wilson and Palomar Observatories, reported that several lines of neutral technetium had been found in spectra of *S*-type stars taken by him with the 100-inch telescope, and more recently in spectra taken by Dr. I. S. Bowen with the 200-inch. The lines were particularly strong in certain variables with periods of about a year.

This is a surprising discovery in view of the fact that technetium is unstable, having a half life of several hundred thousand years. The stellar form of the element may be more stable, or the stars rich in the heavy elements zirconium and barium may somehow produce technetium as they go along, or *S*-type stars may represent a transient phase of stellar existence, Dr. Merrill suggested.

ATOM BUILDING IN HOT STARS

High-luminosity main-sequence stars of types *O* and *B* are believed to exhaust their hydrogen supply within about a billion (10^9) years or less by the conversion of hydrogen into helium by means of the carbon-nitrogen cycle. After this source of energy has been exhausted, the star contracts under its own gravitation, and most theories have required that its temperature reach a billion degrees before another energy-generating process could set in. In the *Astrophysical Journal* for March, E. E. Salpeter, of the Cornell University Laboratory of Nuclear Studies, describes one nuclear process that requires only 200 million degrees, a temperature that is reached a few million years after the contraction has begun.

A series of two reactions converts three helium nuclei into one carbon nucleus:

$$He^4 + He^4 + 95 \text{ kev} \rightarrow Be^8 + \gamma$$

$$He^4 + Be^8 \rightarrow C^{12} + \gamma + 7.4 \text{ mev}$$

In the first of these, the beryllium produced is unstable and most of it breaks down into two helium nuclei again. But as the energy required for the first reaction is available at temperatures over 100 million degrees, the author finds that one part in 10^{10} of the material of the star is kept in the form of Be^8, in dynamic equilibrium. This beryllium easily absorbs a helium nucleus to form carbon, with the emission of energy as shown in the second reaction. In fact, under the same circumstances, successive absorptions of helium can produce oxygen, neon, magnesium, silicon, and heavier elements in decreasing amounts.

Thus, it may be that "a few per cent of all visible stars of mass five times the sun's or larger are converting helium into heavier nuclei, the central temperature being about ten times larger (and radius ten times smaller) than that of a main-sequence star of the same mass."

VOLCANOES AND WEATHER

The absence of major volcanic explosions in the Northern Hemisphere in the past 50 years may account for the tendency for this part of the earth's surface to have grown warmer in that time. In *Scientific American* for April, Dr. Harry Wexler, U. S. Weather Bureau, points out that a single volcanic explosion can block as much as 20 per cent of the incoming solar radiation, and may substantially reduce the heat received at the earth's surface for as long as three years.

A long series of explosions, such as those of Krakatoa, Tarawera, Bandai San, Bogoslof, and Awoe extending from 1883 to 1892, can bring on severe winters; perhaps a really long and violent series can give rise to an age of ice. The Krakatoa explosion in the Dutch East Indies on August 27, 1883, threw some 13 cubic miles of rock, dust, and ash into the air. Clouds of the fine volcanic ash rose 20 miles or more and drifted around the world, affecting atmospheric transmission for three years at such distant places as southern France.

The volcanic ash may provide nuclei for cloud formation, in the manner of modern rainmakers, thereby intensifying the overall shielding of the earth's surface from solar warmth.

Although geological records show no consistent connection between periods of volcanic activity and the ice ages, the former may nevertheless be a factor in long-period climatic changes, Dr. Wexler believes. However, the amount of ash required to cut solar radiation by 20 per cent, if discharged by volcanoes each year for 100,000 years, would make a layer of dust only 1/50 inch thick.

IN THE CURRENT JOURNALS

TURBULENCE IN SPACE, by George Gamow, **Scientific American,** June, 1952. ". . . it now appears that but for the cosmic turbulence of the universe, neither we nor our planet nor the universe as we know it would be in existence."

THE SATELLITES OF JUPITER, by Seth B. Nicholson, **The Griffith Observer,** May 1952. "The story of this famous discovery [the four innermost moons] is best told in Galileo's own words which are quoted here. . . . The four outer satellites are so small and so far from Jupiter that an observer on the planet itself would require a 6-inch telescope to see them."

THE WORLD'S HIGH ALTITUDE LABORATORIES, by Serge A. Korff, **Physics Today,** May, 1952. "A recent survey article on high altitude laboratories [especially for cosmic ray studies] has elicited so much correspondence that it was thought worth-while to present today's roster of such stations in tabular form."

PLANETARY ATMOSPHERES, by William Buscombe, **Leaflet** No. 277, Astronomical Society of the Pacific, May, 1952. "The pioneers of tomorrow may find conditions on Venus, the moon, or Mars not utterly unfavorable for short exploratory visits, if they take along with them a goodly supply of their home-planet's atmosphere."

ETA CARINAE BRIGHTENING

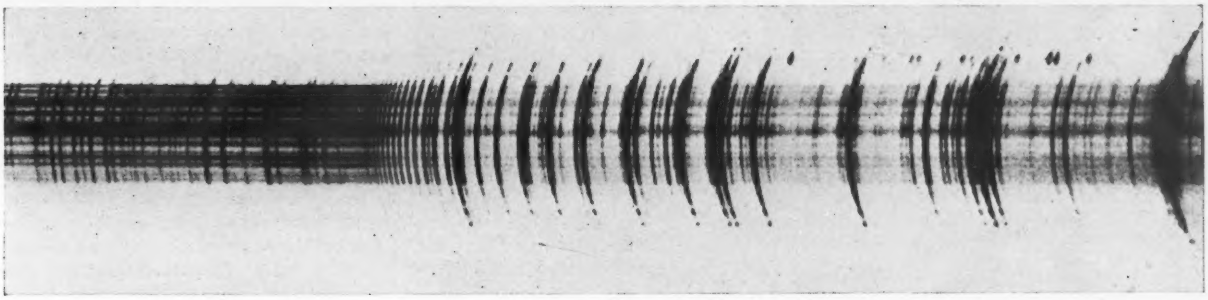
One of the most remarkable novae in the sky, Eta Carinae, appears to be brightening again, according to a press release published in the University of California *Clip Sheet.* At the Commonwealth Observatory in Australia, Dr. Olin J. Eggen, visiting from Lick Observatory, and Dr. Gerard de Vaucouleurs looked for the star and found it four times as bright as they had expected. Dr. Eggen thereupon examined the star with his photoelectric equipment, and he reports it brightening slowly.

Eta Carinae is an unusual type of nova. In the 17th century it was probably a star of the 3rd or 4th magnitude. Very scattered observations between then and 1835 suggest that it may have been variable between the 1st and 4th magnitudes. In 1835, it had brightened to the 1st magnitude, and it became gradually more luminous to a maximum of visual magnitude -1 by 1843, closely rivaling Sirius. It remained brighter than 1st magnitude for over 20 years. Since 1900 it has, until now, been an 8th-magnitude star.

Changes in this Southern Hemisphere star will be watched with interest.

SUPER-SCHMIDT TELESCOPE DESIGNER HONORED

The Magellanic medal of the American Philosophical Society will be awarded in November to Dr. James G. Baker, research associate at Harvard College Observatory and consultant for the Perkin-Elmer Corporation, for his successful design and completion of the super-Schmidt meteor camera (*Sky and Telescope,* July, 1951, page 219). Two such instruments have been operating successfully at the Harvard meteor stations near Las Cruces, N. M., for some time.



A negative print of the flash spectrum in the neighborhood of the head of the Balmer series of hydrogen. This was taken at the eclipse of February 25, 1952, by astronomers of the High Altitude Observatory.

Flash Spectrum Expedition

BY JOHN W. EVANS, *High Altitude Observatory*

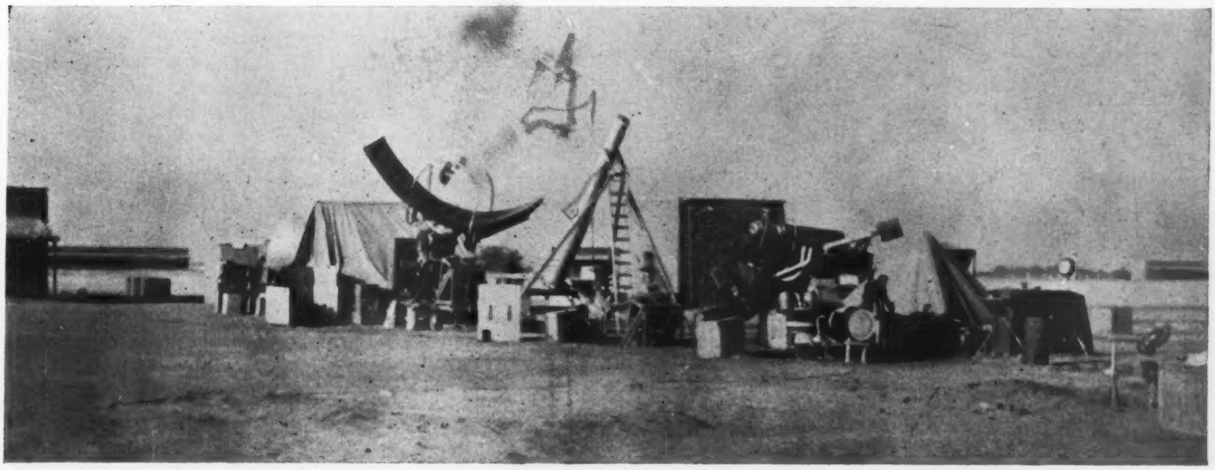
THE High Altitude Observatory eclipse expedition, consisting of Robert H. Cooper, Robert H. Lee, and the writer, set out on January 7, 1952, to observe the total solar eclipse of February 25th at Khartoum in the Sudan. We went as members of the Naval Research Laboratory eclipse group. The principal object of this large expedition was to obtain simultaneous data at radio and visible wave lengths which would lead to a knowledge of the temperature and density gradients of free electrons in the chromosphere. Our own task, which was done under contract with the Naval Research Laboratory, was to observe the spectrum of the chromosphere, the flash spectrum, which is visible for only a few seconds at second and third contacts, when the moon occults the visible disk of the sun and leaves the chromosphere exposed to view.

We found the whole Naval Research Laboratory group a delight to work with. We immediately became an integral part of the expedition and from beginning to end we received help at every stage. Although we came home somewhat the worse for wear in body and mind, with a firm determination to let someone else go next time, the determination has weakened already.

Our preparations at the High Altitude Observatory started in May, 1951. We had three objective-grating spectrographs to build and mount on an equatorial spar which had been built to carry various solar instruments on a good solid pier in a nice quiet observatory. Along about September we realized we should have started in May, 1950, and were wondering how we ever thought we could have our equipment ready for shipment by November. Fortunately, our work was much reduced by the generous loan of two beautiful Ross lenses from the Lick Observatory, and a 24-inch pyrex mirror blank (to be replaced later) from the Mount Wilson Observatory. David Richardson, of the Bausch and Lomb Optical Company, did a rush job on two remarkably perfect gratings, and the Harvard College Observatory loaned a third.

The three spectrographs were to cover the ultraviolet, visible, and near infrared spectral regions, respectively. They were all of 60-inch focal length. The ultraviolet camera was a Schmidt system with a rectangular mirror 24 inches long, 6½ inches wide. The remaining two cameras used the 4-inch Ross lenses.

We were particularly interested in observing the changes in the spectrum at different heights in the chromosphere. This can best be accomplished by Menzel's method of taking motion pictures of the spectrum as the limb of the moon moves across the chromosphere, covering it progressively from the bottom up at second contact or uncovering it from the top down at third contact. The problem of moving the film during the 0.1-second interval between exposures was difficult because we were using a heavy film strip 9½ inches wide, rather than



A general view of part of the eclipse camp at Khartoum, Anglo-Egyptian Sudan, showing radio equipment and the spectrographs of the High Altitude Observatory (to the right of the tent). The three camp views are from Kodachromes taken by Robert H. Lee, High Altitude Observatory.

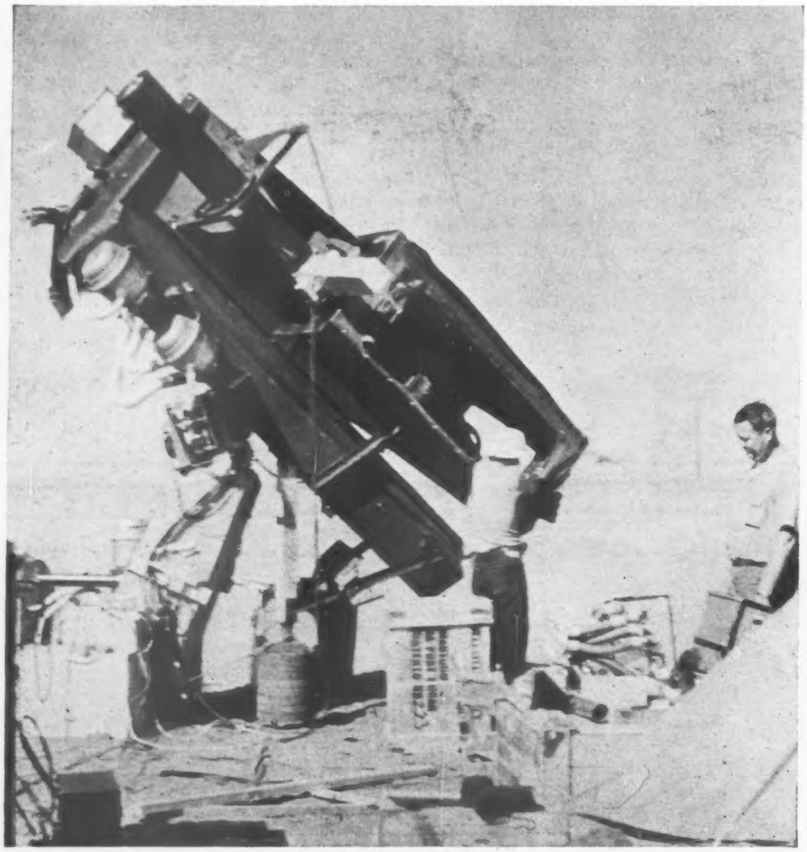
the light 35-mm. film of the conventional motion picture camera. For the purpose, Cooper devised an ingenious pneumatic film magazine in which the only moving parts were the film itself and the leaves of a focal-plane shutter. The film was literally blown past the film gate by a powerful draft from a battery of household vacuum cleaners controlled by external electrically operated valves. This "slurp" mechanism worked beautifully in the laboratory at Boulder, but we found that the sliding valves could be easily jammed by the blowing sand of the Sudanese desert.

By superhuman efforts on the part of our instrument makers, opticians, electronics engineers, and (toward the last) secretaries, the equipment was finished and packed by November 1st. It was shipped to the Sudan by sea with the Naval Research Laboratory equipment. We arrived at Khartoum on January 13th via Military Air Transport Service with the rest of the NRL expedition.

Several expeditions from various countries were already there, and others kept coming right up to the week before the eclipse. Most interesting to us were the combined project of Drs. Redman, Zanstra and Houtgast, and that of Dr. Abetti. They were planning to observe the chromosphere with both slit and slitless spectrographs, and would obtain results comparable with our own. However, we witnessed the strange phenomenon of scores of astronomers in one place, all too busy to stop and talk any astronomy except for the eclipse. They had a deadline to meet that could not be postponed, and were singlemindedly sticking to business. I am sure they all felt a sense of lost opportunity as keenly as we, but the work had to be done, and most of the equipment was barely ready in time.

Nevertheless, the eclipse astronomers held four meetings at the University College in Khartoum, discussing radio astronomy on January 23rd, the chromosphere on January 28th, positional astronomy and geodetic work on the 30th, and the corona on February 4th. The reports given at these meetings, which described various expedition equipment and observing programs, have been published in *The Observatory* for April, 1952.

The site selected for our instruments was about three miles south of the city on the open desert. We found it very hot, and the sand carried by the unobstructed wind was a serious nuisance which continually threatened damage to any unprotected parts of our delicate optical equipment. The discomfort of our days at the observing site was mitigated, however, by the luxury of the Grand Hotel where we stayed, surrounded by shade trees and waiters with lemonade and other cooling concoctions.



The spectrographs of the High Altitude Observatory. Robert H. Cooper is working on the instruments; David Hawkins, Naval Research Laboratory, is at the right.

The work of setting up our instruments proceeded steadily. The anticipated unforeseen difficulties and emergencies duly appeared, and were successfully dealt with. Dr. Hagen's group assembled their highly elaborate radio gear with an amazing lack of fuss or pressure, and were running tests days before the eclipse.

On the night of February 14th, at 12:15 a.m., I had the misfortune (a polite term for absence of good sense) to fall from the spectrograph mounting and break my leg, not having been inoculated for this particular malady. This left us in a rather critical situation, since all the optical adjustments of our spectrographs still remained to be done, and this work was my particular province. The doctors and staff at the very modern Khartoum Civil Hospital, however, did everything possible to help.

I set up a micrometer microscope on a table beside my bed of exasperation to measure our focus films and compute correct focal settings for all three spectrographs. By the 18th I was permitted to start going back and forth to the observing site (in a car generously provided by Dr. G. Van Biesbroeck, of Yerkes Observatory) and could hobble around on crutches, dragging my cast behind me, so to speak. It was Cooper and Lee, however, who saved our project. They worked inhuman hours, day and night, and endured my worried heckling with unvarying patience, keeping me in a comfortable chair with my leg on a pillow much of the time. By eclipse day I had gotten used to the cast and the crutches and could get around with some semblance of agility.

Four hours ahead of the eclipse, after a full night of work, we were all ready. Many things were unchecked. The focus particularly worried us. We had focused by the Hartmann method, which required only one exposure for each spectrograph, and measurements from which the correct focus could be calculated. There had been no time, however, for any exposures to confirm the accuracy of this procedure. We had had no opportunity for any rehearsal or drill of any sort. After a good breakfast we huddled, and divided up the responsibilities. They fell mainly to Cooper and Lee. My own job was to watch the spectrum of the vanishing crescent of the sun as totality approached, and give the word to start when the photospheric continuum disappeared. Lee would then press the button that started the automatically controlled program of exposures. Dur-

ing totality Cooper was to change the pointing of the spectrograph unit from the east to the west limb. The rest was up to the machinery.

A few minutes before totality Cooper glanced through the sighting telescope to find that someone had carelessly bumped the instrument and knocked it off the sun, but it was easily realigned. Lee diplomatically waited until after the eclipse to tell us that the electronic oscillator which controlled the right-ascension drive motor had failed. As an electronics expert he is always suspicious of vacuum tubes, and had forehandedly provided a spare oscillator, which he then connected by the flick of a switch.

Ten seconds before the predicted time of second contact our exposures began. I sat in a camp chair with my back against a heavy crate (so I could not tip over at the wrong moment) and watched the band of photospheric continuum shrink down. Strangely, it was a moment I had been dreading for some months. Often the instant of onset of totality is confused by the presence of Baily's beads, light shining through lunar valleys. This would have complicated the job and made it difficult to decide the correct moment to start the program. No such trouble appeared, however. The photospheric spectrum contracted smoothly and continuously until it vanished, and I could give the word with complete confidence. I watched the bright lines of the flash spectrum appear and quickly fade out, except for the few brilliant high-level lines, in a startlingly short time. It seemed like but a fraction of a second, and I fully appreciated the term "flash spectrum" at that moment. After the exposures for second contact were over I anxiously watched Cooper operate the mechanism that shifted the spectrographs to the west limb. He did it with the utmost deliberation and it must have taken him 10 seconds that seemed like as many hours. We then took two exposures of 10 and 30 seconds to record the coronal emission lines. After that our responsibilities were over. We watched the truly gorgeous corona until the cameras began to click again for the flash at third contact. A few seconds later it was all over. The limb of the sun reappeared. Everyone relaxed, and began wandering around asking everyone else if his equipment had run well (it had in every case). The radio observers were still hard at it, since their program ran through the partial phases and for some hours beyond. But they were happy. Totality was the most important phase, and they had obtained beautiful records of it.

After the eclipse we made exposures on a standard lamp to provide calibrations which would permit us to determine the intensities of the chromospheric lines quantitatively. On the 26th when

The author, although handicapped, is here adjusting the slit on the collimator.

we unloaded our magazines to develop the film, we discovered that the film transport had not functioned for these exposures. The eclipse spectra were there, however, although there were several double exposures. Subsequent examination showed that they were, on the whole, excellent, and in good focus. The infrared films were definitely underexposed, giving only a faint record of the Paschen hydrogen series and several brighter lines. The visible and ultraviolet were both well exposed and the spectra were beautiful. The loss of our calibrations was not serious, as they could be repeated.

The following night we made our calibration exposures over. Since we had only two days to disassemble the instrument and pack it, we left the development to be done at home. With the help of a gang of Sudanese workmen, we finished the packing on time, and happily boarded the MATS plane.

We now have a long and interesting job ahead of us. The films will be traced with a microphotometer to determine the intensities of the lines at different heights in the chromosphere at several points on the solar limb. Our primary aim is to determine the temperature and the density of the free electrons in the chromosphere as a function of height. However, the films naturally contain much more information than this, and it will take some time to extract it all.

GALILEO'S VISITS TO ROME

(Continued from page 213)

denounced to the Holy Office. Thus was the stage set for the tragedy of Galileo.

On February 19, 1616, 11 qualifiers of the Holy Office were asked for their opinion on two propositions extracted from the book. These clergymen were experts in sacred theology and not in natural science, and it is typical of the times that their opinion was asked and given not so much on the scientific evidence for the theory as on its theological implications. On February 24th these consultors submitted to the cardinals, members of the tribunal of the Inquisition, the following unanimous opinion.

1. The proposition that the sun is the center of the world and is entirely immovable from its place is stupid and absurd philosophically, and formally heretical, because it expressly contradicts statements made in many places of Sacred Scripture, according to the literal meaning of the words and according to the common explanation and opinion of the Holy Fathers and learned theologians.

2. The proposition, that the earth is neither the center of the world nor immovable, but that it moves as a whole and also with a diurnal motion, is open to the same censure in philosophy and, theologically considered, is at least erroneous in faith.

The next day Pope Paul V presided over the usual Thursday plenary session of the cardinals of the Inquisition, in the Dominican Convent of Santa Maria sopra Minerva, in Piazza Minerva near the Pantheon. The verdict of the consultors was accepted, and the Pope asked Cardinal Bellarmine to send for his friend Galileo and advise him to relinquish his opinion. Failing that, the Dominican commissary of the Holy Office was to command Galileo in the presence of witnesses thenceforth not to teach, defend, or discuss this opinion verbally or in writing, under pain of imprisonment.

(To be concluded)

ECLIPSE OBSERVATIO[N

DURING the total solar eclipse of February 25th, a B-29 Superfort flew about six miles high over the Red Sea and Saudi Arabia, operating as part of the U. S. Air Force eclipse expedition under the leadership of Col. Paul C. Schauer, commander of the Aeronautical Chart and Information Service. It carried three groups of scientists, all making observations for research programs sponsored by the Geophysics Research Division, Air Force Cambridge Research Center, Air Research and Development Command. The three programs consisted of spectrographic observations of the radiation from the earth's upper atmosphere, measurements on the polarization of the light coming into the shadow from the sunlit portion of the atmosphere during the eclipse and studies of the airglow spectrum, and sky brightness measures extending to about 30 degrees from the sun for detection of the zodiacal light.

Most of the instruments were mounted in the project plane and given preliminary testing at Griffiss Air Force Base in Rome, N. Y., after which the plane was flown to Saudi Arabia. It was based at Dhahran for a week before the eclipse, where final adjustments and test flights were made.

During the month of February an occasional sandstorm occurs in this area, and on February 22nd and 23rd Dhahran experienced such a storm. The scientific equipment, safely enclosed in the B-29, was kept free of dust, however, and the storm had completely settled by the 25th, which was quite clear at Dhahran.

The members of the expedition decided to observe the eclipse near the Red Sea (western) coast of Saudi Arabia. There are few accurately positioned landmarks in the Arabian Desert, and because of the relative inaccuracies of celestial navigation, the navigator felt that the best method lay in picking out a point on the seacoast visually and by radar.

About five minutes before second contact (the beginning of totality), which occurred about local noon, the plane was 32,000 feet true altitude above the coast, heading roughly in a northeasterly direction. Its ground speed was a little over 350 miles per hour, so that the duration of the eclipse was increased from three to about 3½ minutes.

About one minute before the start of totality, the shadow was seen in the distance moving over the surface of the earth as it approached the plane. The pilot, Capt. O. Knapp, and copilot, Capt. B. Fielder, reported a magnificent view of the receding shadow of the moon after totality, as it whisked away.

The following preliminary accounts describe the scientific work undertaken, and the various observations made from the B-29.

THE AIRGLOW SPECTRUM

The experiments of the Ionospheric Laboratory of the Geophysics Research Division were under the direction of R. M. Chapman and N. C. Gerson, and were carried out by J. W. Chamberlain. A Gaertner quartz spectrograph, equipped with an evaporated step filter over the slit and having a dispersion of about 200 angstroms per millimeter at Hγ, was mounted in the plane before it left the United States. A plexiglas window that was essentially transparent for wave lengths greater than 3000 angstroms was specially installed in the plane. The spectrograph was mounted in such a manner that when the plane flew along the path of the eclipse, the instrument would observe the sky about 90 degrees from the sun.

During the final week before the eclipse, in addition to instrument tests, spectrographic observations were made of the twilight sky and the daytime scattered light. These observations will eventually be measured by microphotometer and compared with those made during the eclipse.

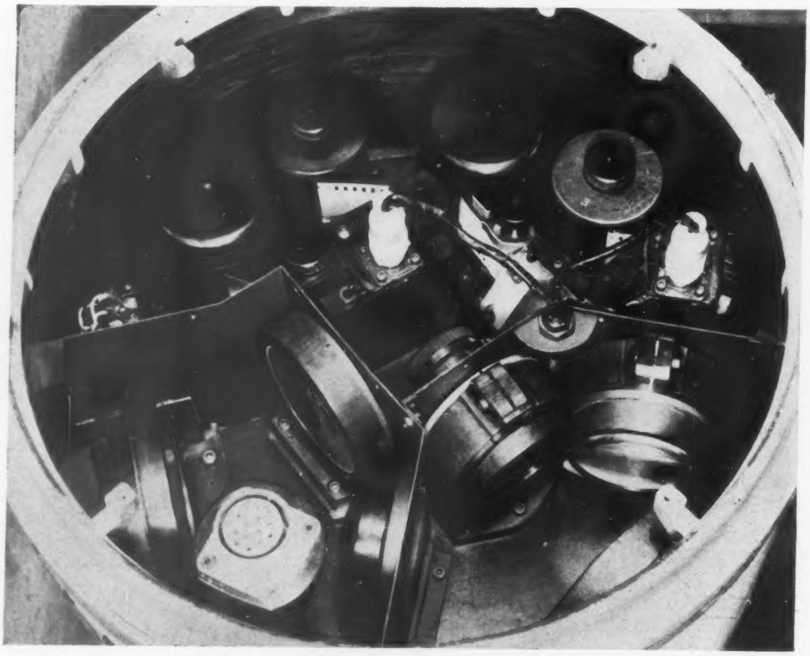
At eclipse time, just before, during, and just after totality, spectrograms of the light of the sky were made. Also, the sky 90 degrees from the sun was observed visually through polaroid. The indications were that the polarization was qualitatively the same as it is outside of eclipse. No quantitative measures were made, but if the scattered light is sufficiently polarized during an eclipse, a polarizing device could be used to increase the signal-to-noise ratio in spectrograms taken at a large angle from the sun.

After the eclipse, the plane flew directly to Tripoli, Libya, and the spectrographic plates were developed there. The spectrum made during totality was considerably underexposed. These plates will soon be microphotometered in an effort to measure emission lines in the earth's airglow spectrum and to obtain the intensity distribution with wave length of the scattered light.

R. M. CHAPMAN
J. W. CHAMBERLAIN
Geophysics Research Division, AFCRC

SKY SPECTRA

Previous spectrographic observations have indicated the presence in sky spectra of some luminous emission in the extreme red of the visible region and in the near infrared region. We have obtained the previous data by spectrographs carried to 100,000 feet above the earth by means of large plastic balloons. The data are not quite conclusive, and it was the purpose of our University of Denver eclipse expedition group to attempt to obtain sky spectra at short intervals preceding totality and just sub-



The optical section of the University of Denver eclipse spectrograph. The collimator section is in the lower left quarter; the light passes from there to the grating section in the lower right, thence to the films in the upper section.

IONS FROM A B-29

sequent to the reappearance of the sun, to observe any change in the ratio of disappearance and appearance intensities of the daylight luminescence.

The instrument was a reflection grating spectrograph constructed for the expedition and for subsequent use in observations from rockets. The spectrograph was somewhat unusual in several features. It was automatic in operation, even to being turned on five minutes before totality by a time-clock switch mechanism, which was set two hours previous to totality and could have been set four hours before the beginning of observations.

The spectrograph was an f/1.5 instrument, and carried two camera sections, one for the infrared region and a second for the ultraviolet. The collimator section consisted of a specially designed reflection system, lens corrected, in which a ruled cut line on the mirror surface of a quartz disk acted as the entrance slit and the mirror served as part of the collimator reflection system. The quartz correction lens of a Maksutov-Bouwers type gave excellent correction for the incoming light despite the f/1.5 value for the collimator system.

Exposure sequences of four, 10, and 25 seconds were obtained by the device of using a cam-operated focal-plane shutter on each of the cameras. At the beginning of each recording, a picture was taken of the master timing clock to indicate alongside each spectrum the exact time it was made. The films were Eastman Linagraph Panchromatic for the ultraviolet and visible regions, Eastman 1-N for the extreme red and infrared, both 35-mm. film that was advanced automatically at the conclusion of each timed sequence.

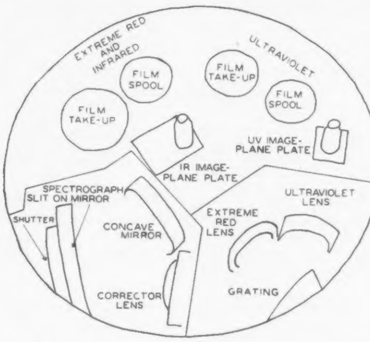
To provide heat insulation, and thereby minimize condensation at the quartz window placed in the airplane as a port through which the spectrograph could look, the window was of double quartz, with the two elements separated by 1/8 inch. A similar precaution was taken in the mounting of photoelectric guard cells, so placed as to close the slit shutter should sunlight come within a 15-degree angle of the spectrograph slit before or after the period of totality. Despite our precaution with respect to the cooling of windows by the cold air encountered at 30,000 feet, the window of the spectrograph was partially obscured by frost condensed inside the plane, with a resulting reduced transmission.

The spectroscopic equipment was designed and constructed at the University of Denver by Byron E. Cohn, Marvin E. Juza, Theodore Maher, James Brooks, Dana T. Warren, Alfred Goddard, and Frank R. Speck. The preliminary tests at Griffiss Air Force Base were conducted by Mr. Cohn, Mr. Juza, and John G. Tomkinson. The latter two men accompanied the equipment to Dhahran. The expedition film was flown back to the United States and was developed in Denver.

It is reported with regret that the eclipse observation did not give final and conclusive evidence of daylight luminescence from different rates of appearance and disappearance, so this method of verification must be postponed until the next solar eclipse. Meanwhile, the problem will be attacked from another direction with experiments conducted from rockets and balloons.

BYRON E. COHN
University of Denver

The University of Denver eclipse equipment installed in the B-29. The spectrograph is in the cylindrical container in the upper right. The external initiation control panel is at the lower right. John G. Tomkinson is checking the apparatus.



The principal parts of the spectrograph pictured on the opposite page are identified in this sketch.

THE ZODIACAL LIGHT

A total eclipse of the sun affords the opportunity for the observation of many phenomena which would otherwise go undetected, or which would require highly specialized apparatus for their study. Among these elusive items is the zodiacal light, or especially that part of it extending from about five degrees to 30 degrees from the sun. The part within five degrees of the sun (where it blends with the corona) can be photographed with a coronagraph, while that part beyond 30 degrees can be photographed when the sun is just below the horizon. However, light in the interval between five and 30 degrees from the sun along the glow (the glow here is presumed to exist though it has never been conclusively observed) is the really important part so far as theories of the origin of the zodiacal light are concerned. For this region the different theories yield their most divergent results, and hence observational data here should give valuable information in determining the most satisfactory theory.

The zodiacal light investigation carried on by the University of Colorado involved the problem of making observations in the critical region during the eclipse. The camera, a powerful Schmidt-type instrument, was designed to yield photographs so that relative intensities and depolarization factors could be found from photometric studies of the negatives.

On February 4th, the University of Colorado group traveled to Rome, N. Y., to install the eclipse equipment in the B-29, and then went on to Saudi Arabia. Analysis of the data is now in process, and should be completed sometime during this summer.

W. B. PIETENPOL
University of Colorado

ED. NOTE: The University of Denver research reported here is under Contract W19-122 ac-16, and that of the University of Colorado is under Contract W19-122 ac-9, both with the Air Force Cambridge Research Center, Air Research and Development Command.

For a description of the activities of the Geophysics Research Division, AFCRC, see an article by Director H. E. Landsberg in **Weatherwise** magazine for June, 1952. **Weatherwise** is published bi-monthly for the American Meteorological Society, 3 Joy St., Boston 8, Mass.

Amateur Astronomers

Southeast Region Meets at Bradley Observatory

The Southeast regional convention of the Astronomical League on May 17-18 brought to Bradley Observatory at Agnes Scott College in Decatur, Ga., about 85 members and guests from six states. A highlight of the convention took place Saturday night, when dinner was served on the roof of the observatory. Clearing skies permitted the use of and comparisons among a battery of telescopes ranging in size from the 30-inch reflector in the observatory dome down to an RFT-in-arms.

The Barnard Astronomical Society of Chattanooga will be host to the 1953 regional convention.

Regional officers for the coming year are: chairman, Richard C. Davis, North Carolina State College, Raleigh; vice-chairman, Chandler H. Holton, Atlanta, Ga.; secretary, Mrs. Karel Hujer, Chattanooga, Tenn.; treasurer, P. O. Parker, Griffin, Ga.

Acquaintances were formed and ideas exchanged during the meeting which should bear fruit in future growth and strength of this recently formed far-flung region of the league.

C. H. Holton
167 Fourth St. N. W.
Atlanta, Ga.

The Southeast regional convention, May 18, 1952. Photo by Lee Studio.

THIS MONTH'S MEETINGS

Dallas, Tex.: Texas Astronomical Society. July 28, 8 p.m., field meet, home of Mrs. W. L. Oliver, 1446 Glen St.

Indianapolis, Ind.: Indiana Astronomical Society. July 6, 8 p.m., observation meeting, Butler University. Clark Hicks, "Our Moon."

OFFICERS OF THE AMATEUR ASTRONOMERS ASSOCIATION

New officers of the Amateur Astronomers Association for the year beginning June 1, 1952, were recently elected by the New York organization. Leo Mattersdorf is the new president, succeeding Dr. C. S. Brainin; vice-presidents are Mrs. Virginia Geiger, Hazel Boyd, W. Wallace Benjamin, and Jane S. Davis. George V. Plachy was re-elected secretary and Henry T. Kirkebye, treasurer.

Information about the Amateur Astronomers Association, which celebrated its first quarter-century of activity this year, may be had by addressing the secretary at the society's headquarters, American Museum of Natural History, New York 24, N. Y.

Planetarium Notes

BALTIMORE: *Davis Planetarium.* Maryland Academy of Sciences, Enoch Pratt Library Building, 400 Cathedral St., Baltimore 1, Md., Mulberry 2370.

Schedule: 4 p.m. Monday, Wednesday, and Friday; Thursday evening, 7:45, 8:30, 9:30 p.m. Admission free. Spitz projector. Director, Paul S. Watson.

BOSTON: *Little Planetarium.* Boston Museum of Science, Science Park, Boston 14, Mass. Richmond 2-1410.

Schedule: Tuesday through Friday, 3 and 4 p.m.; Saturday, 11 a.m., 2, 3, and 4 p.m.; Sunday, 2, 3, and 4 p.m. Spitz projector. Acting director, John Patterson.

BUFFALO: *Buffalo Museum of Science Planetarium.* Humboldt Parkway, Buffalo, N. Y., GR-4100.

Schedule: Sundays, 2:00 to 5:30 p.m. Admission free. Spitz projector. For special lectures address Elsworth Jaeger, director of education.

CHAPEL HILL: *Morehead Planetarium.* University of North Carolina, Chapel Hill, N.C.

Schedule: Daily at 8:30 p.m.; Saturday and Sunday at 3:00 p.m. Zeiss projector. Manager, A. F. Jenzano.

CHICAGO: *Adler Planetarium.* 900 E. Achsah Bond Drive, Chicago 5, Ill., Wabash 1428.

Schedule: Mondays through Saturdays, 11 a.m. and 3 p.m.; Sundays, 2:30 and 3:30 p.m. Zeiss projector. Director, Wagner Schlesinger.

KANSAS CITY: *Kansas City Museum Planetarium.* 3218 Gladstone Blvd., Kansas City 1, Mo., Chestnut 2215.

Schedule: Saturday, 3:30 p.m.; Sunday, 3:00 and 5:00 p.m. Spitz projector. Director, Charles G. Wilder.

LOS ANGELES: *Griffith Observatory and Planetarium.* Griffith Park, P. O. Box 9787, Los Feliz Station, Los Angeles 27, Calif., Olympia 1191.

Schedule: Wednesday and Thursday at 8:30 p.m.; Friday, Saturday, and Sunday at 3 and 8:30 p.m.; extra show on Sunday at 4:15 p.m. Zeiss projector. Director, Dinsmore Alter.

NASHVILLE: *Sudekum Planetarium.* Children's Museum, 724 2nd Ave. S., Nashville 10, Tenn., 42-1853.

Schedule: Sunday, 2:45, 3:30, 4:15. Spitz projector. Director, William G. Hassler.

NEW YORK CITY: *Hayden Planetarium.* 81st St. and Central Park West, New York 24, N. Y., Trafalgar 3-1300.

Schedule: Mondays through Fridays, 2, 3:30, and 8:30 p.m.; Saturdays, 11 a.m., 2, 3, 4, 5, and 8:30 p.m.; Sundays and holidays, 2, 3, 4, 5, and 8:30 p.m.; Wednesdays and Fridays, 11 a.m., for school groups. Zeiss projector. Chairman, Robert R. Coles.

PHILADELPHIA: *Fels Planetarium.* Franklin Institute, 20th St. at Benjamin Franklin Parkway, Philadelphia 3, Pa., Locust 4-3600.

Schedule: Tuesdays through Sundays, 3 p.m.; Saturdays, 11 a.m.; Saturdays, Sundays, and holidays, 2 p.m.; Wednesdays, Fridays, and Saturdays, 8:30 p.m. Zeiss projector. Director, I. M. Levitt.

PITTSBURGH: *Buhl Planetarium and Institute of Popular Science.* Federal and West Ohio Sts., Pittsburgh 12, Pa., Fairfax 4300.

Schedule: Mondays through Saturdays, 2:15 and 8:30 p.m.; Sundays and holidays, 2:15, 3:15 and 8:30 p.m. Zeiss projector. Director, Arthur L. Draper.

PORTLAND, ORE.: *Oregon Museum of Science and Industry Planetarium.* 908 N.E. Hassalo St., Portland 12, Ore., East 3807.

Schedule: Saturday, Sunday, and Wednesday, 4:00 p.m.; Tuesday, Thursday, and Friday, 8:00 p.m.; Saturday show for children only, 10:30 a.m. Spitz projector. Director, Stanley H. Shirk.

SPRINGFIELD, MASS.: *Seymour Planetarium.* Museum of Natural History, Springfield 5, Mass.

Schedule: Tuesdays, Thursdays, and Saturdays at 3 p.m.; Tuesday evenings at 8 p.m.; special star stories for children on Saturdays at 2 p.m. Admission free. Korkosz projector. Director, Frank D. Korkosz.

STAMFORD: *Stamford Museum Planetarium.* Courtland Park, Stamford, Conn.

Schedule: Sunday, 4:00 p.m. Special showings on request. Admission free. Spitz projector. Director, Ernest T. Luhde.

TERMINOLOGY TALKS—J. Hugh Pruett

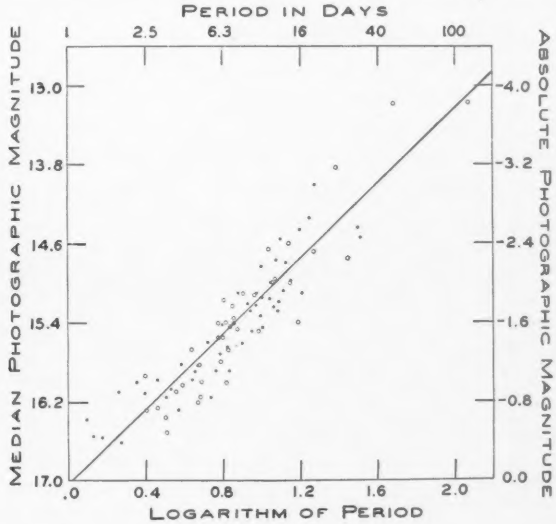
Period-Luminosity Diagram

Fundamental characteristics of the stars themselves, in the case of certain variables, lead us to the equally important subject of distances and how they may be derived by means of the period-luminosity relation.

It was found many years ago by Harvard astronomers that among the Cepheid variables in the Magellanic Clouds there exists a close relationship between such a star's median brightness (average between maximum and minimum) and the period of time for a complete cycle of variation. If, for example, one star has a period of seven days and another of 10 days, the first is of a lower apparent brightness than the second. The interesting story of this discovery and of the way it has since been used to determine the distance to faraway Cepheids is given in almost any astronomy text.

This relation is actually one of period and intrinsic luminosity or absolute magnitude. The stars in the Clouds are so far away, however, that they may all be considered to be at practically the same distance from us; therefore, as the accompanying diagram shows, merely by correcting for the distance of the Clouds (about 80,000 light-years), their apparent magnitudes may be converted to absolute magnitudes. The correction is 17.25 magnitudes, but about 0.3 magnitude is accounted for by interstellar absorption.

Ample observations in our own and other galaxies have shown that this standard period-luminosity curve may be applied to all Cepheid variable stars. From the measured period of a star's variation its absolute magnitude may be determined. This, combined with the observed apparent magnitude, permits calculation of the star's distance. In his book, *Galaxies,* Dr. Harlow Shapley gives the simple formulae by which these calculations of tremendous celestial distances are made.



The standard period-luminosity diagram, plotted for 88 Cepheid variables in the Magellanic Clouds. Those in the Small Cloud are dots; in the Large Cloud, small open circles. Differences among the stars' characteristics and in their individual distances, as well as observational errors, account for the scatter along the mean curve. Harvard Observatory diagram.

BOOKS AND THE SKY

RADIO ASTRONOMY

Bernard Lovell and J. A. Clegg. Chapman and Hall, 37 Essex St., London W. C. 2, 1952. 238 pages. 16s.

THE SPEED of scientific advances during the past few years is well indicated by the fact that we now have a complete book on a subject which was practically nonexistent as recently as the end of World War II. In **Radio Astronomy,** two experts in the field have combined to give a very readable, interesting, and authoritative survey of this most recent branch of astronomy.

Although prior to 1945 there were a few isolated cases of interesting astronomical observations on the longer electromagnetic wave lengths, it was only with the utilization of equipment developed during the war years that radio astronomy really became a subject in its own right. A large part of the pioneer work in this field was done by the English observers.

In this book by Lovell and Clegg, the first two chapters form an introduction to basic astronomy, including co-ordinate systems, star maps, and the planetary orbits. The next two chapters give a similar brief introduction to the fundamental properties of radio aerials, detection of radio noise, and the pulsed radar technique. These subjects are covered clearly and without advanced mathematics, but so briefly that additional elementary texts in either astronomy or radio will help those unfamiliar with these fields.

Seven chapters are next devoted to the development of the radio observations of meteors, their orbits, and their connection with ionization studies of the upper atmosphere. As is natural, the English observations are covered in considerably more detail than those of other countries. In a subject as recent as this one it is difficult to give a perfectly uniform coverage, especially since much of the work has not yet been published in detail.

The reader will be surprised at the wealth of new information which radio techniques have given us in the field of meteoric astronomy. This is particularly true of the Manchester observations of the daytime meteor showers. These daylight recordings have confirmed some of the well-known night showers and have already added at least 10 new meteor showers that are only present when the sun is above the horizon. Incidentally, I might note here that the reference to radiant determination by McKinley and Millman, top of page 92, should be **Canadian Journal of Research, A 27,** 53, 1949. The paper that has been referred to describes a one-station method of radiant determination.

The radio measurement of meteor velocities has also yielded important results. Here, for the first time, reliable velocities have been determined for faint meteors at and below the limit of naked-eye visibility. Both the English observations, and McKinley's very extensive investigation at Ottawa in measuring over 10,000 meteor velocities, show a virtual absence of meteors moving about the sun in orbits with velocities that are hyperbolic.

Chapters 12 to 15 deal with the measurement of radio waves from our sun. This is a subject of particular interest in connection with theories of the outer solar atmosphere and of the radio blackouts which have been associated with solar flares.

Galactic radio noise observations are covered in Chapters 16 to 19. Much of the pioneer work in this field was carried out by Reber in the United States. More recently, the discovery of the mysterious radio stars, which emit no detectable light in the visible part of the spectrum, has occupied the attention of observers in several countries. Short concluding chapters describe radio studies of the aurora, of the moon, and of the planets, the last a possibility of the future.

There are a few small errors or omissions in the astronomical material. The autumnal equinox is September 23rd on the average, not September 21st as given on page 18; and the sun, not the earth, is at the first point of Aries on March 21st, page 30 and Fig. 14. Three of the 10 brightest stars in the sky, Rigel, Achernar, and Canopus, have been omitted from the map, Fig. 7; and 100 kilometers equal 62 miles, page 25.

The most noticeable astronomical omissions occur in the table of planetary data in Appendix 1, which seems to date from shortly after the discovery of Pluto in 1930 and omits various elements of Pluto's orbit since determined. Also not listed are the four satellites of large planets discovered in the period 1938-1949, while included is the 10th satellite of Saturn, now generally discredited.

In reference to the asteroids, on page 27 it is stated that the majority are less than one kilometer in diameter. This is quite likely true for the great bulk of undiscovered objects but very few of those found to date are as small as this. It is also felt that, according to the best estimates, the statement on page 131 that the average meteor is less than one millimeter in diameter is true of the telescopic meteors but not of the average visual meteor.

However, these points are minor and do not detract from the value of the

book as a lively and inspiring document on current research. The illustrations are numerous and excellently reproduced. There are useful lists of references at the end of every chapter. I can sincerely recommend this volume to both the astronomer and the general science reader.

PETER M. MILLMAN
Dominion Observatory, Ottawa

THE EXACT SCIENCES IN ANTIQUITY

O. Neugebauer. Princeton University Press, Princeton, 1952. 191 pages. $5.00.

DR. NEUGEBAUER'S is a scholarly book on a specialized subject. "I am convinced," he says, "that specialization is the only basis of sound knowledge." Even though he is "compelled for once to abandon all learned apparatus and to pretend to know when actually I am guessing," he writes with an economy of expression that makes considerable demands on the reader.

The book discusses the origin of number systems, Babylonian and Egyptian mathematics and astronomy, and Hellenistic science. The author not only gives a clear and readable account of what we know about these subjects, but also takes pains to explain the basis of our knowledge, so that the book touches almost as much on the methods and problems of archeological research as on the history of science.

Dr. Neugebauer indulges in no loose statements about the "lore of the ancients." Several time-honored myths are exposed as such, for instance that of the "legendary accuracy" of the astronomical observations of the Babylonians, and the alleged scientific and mathematical secrets hidden in the pyramids of Egypt. He devotes an especially interesting note to the saros, "a beautiful example of the creation of generally accepted historical myths," and discounts the idea that Thales predicted the eclipse of 585 B.C. by this means, or indeed predicted it at all.

Instead of fascinating but unsound scientific myths, the book presents a solid and satisfying diet of carefully sifted fact. The serious student will find it of absorbing interest, but it is in no sense a popular treatment of the subject. The book is excellently produced and printed, and the illustrations are beautiful.

CECILIA PAYNE-GAPOSCHKIN
Harvard College Observatory

PALOMAR OBSERVATORY

D. Alter and C. H. Cleminshaw. Griffith Observatory, Los Angeles, 1952. 76 pages. 90¢.

THIS DESCRIPTIVE BOOKLET was undoubtedly prepared in response to the great demand by people in Southern California for information about the new observatory and the 200-inch telescope. It is a well-organized guide to the observatory, the instruments, and the program of observations at Palomar. Included are five addresses given at the dedication of the Hale telescope, statistical data for both the 200-inch and 48-inch telescopes, and an excellent elementary account of the principle of the Schmidt camera.

The many illustrations are very good except for a few of the photographs of nebulae, particularly NGC 4486 and the Omega nebula, which are reproduced with so much contrast that much of the detail is lost.

PHILIP C. KEENAN
Perkins Observatory

NEW BOOKS RECEIVED

THE ATMOSPHERES OF THE EARTH AND PLANETS, *G. P. Kuiper*, editor, 2nd edition, 1952, *University of Chicago Press.* 434 pages and 16 plates. $8.50.

This is the second edition of a book reviewed on these pages just three years ago. The current work has had extensive revision, so that its findings are well up to date as of early 1951. Eight chapters cover the earth's atmosphere and related problems; infrared and spectroscopic observations of the solar system are selectively discussed; and the editor himself contributes 100 pages on planetary atmospheres and their origin. Finally, G. Herzberg describes experiments in laboratory spectra obtained with long paths.

THE NATURE OF SOME OF OUR PHYSICAL CONCEPTS, *P. W. Bridgman*, 1952, *Philosophical Library.* 64 pages. $2.75.

Three lectures given at the University of London in 1950 are here reprinted. The author states that he is attempting "a more articulate analysis than hitherto of the operations involved in some of our physical concepts, particularly an analysis of the operations into their instrumental and their 'paper and pencil' and verbal components." Among other things, the first lecture examines the concepts of field and empty space; the second, the fundamental concepts of thermodynamics; the third, electrical phenomena in massive conductors.

PROCEEDINGS OF THE LONDON CONFERENCE ON OPTICAL INSTRUMENTS — 1950, various authors, 1952, *Wiley.* 264 pages. $7.00.

The papers and symposia given at the London conference, which was a co-operative meeting of the International Optical Commission and various British societies, are presented here. The general subjects are photographic and projection lenses, reflecting microscopes, gratings and grating instruments, phase-contrast microscopes, spectrophotometers, reflecting telescopes, new optical materials, and several miscellaneous papers.

COSMOLOGY, *H. Bondi*, 1952, *Cambridge University Press.* 179 pages. $4.50.

As one of the Cambridge monographs on physics, this book presents the subject of cosmology as a branch of physics in its own right. Principles of cosmology are discussed in the first part of the book, then observational evidence, and then the various cosmological theories, past and current.

THE ARTIFICIAL SATELLITE, *L. J. Carter*, editor, 1952, *British Interplanetary Society*, 12 Bessborough Gardens, London S.W. 1, England. 74 pages. 75 cents; 5s 6d; paper bound.

This volume concerns the Second International Congress on Astronautics, which met in London in 1951, and includes the proceedings and texts or summaries of the technical papers. The material is reprinted from the 1951 annual report of the BIS and the November, 1951, BIS *Journal.*

BASIC ASTRONOMY, *Peter van de Kamp*, 1952, *Random House.* 400 pages. $3.75.

The author presents the science of astronomy for the layman— this is not a formal textbook — but discusses his topics sufficiently "to make the reader aware of the methods employed by the astronomer, and of the development of his ideas and knowledge." The four main sections are entitled: "A Survey of the Solar System"; "The Mechanics of Stars and Planets"; "The Physical-Chemical Properties of Sun and Stars"; "The Milky Way System and Beyond."

GLEANINGS FOR ATM's

EDITED BY EARLE B. BROWN

How to Mold and Pour Your Own Castings — I

THE ART of molding aluminum and brass castings has been brought to its present excellence after many decades of labor and experiment. As an amateur telescope maker, I have—for many years—been making all the necessary castings for my own telescopes and other astronomical instruments. Some time ago I conceived a plan which I hoped would simplify molding procedures for the benefit of amateur telescope makers. After a great deal of research, I have accomplished my purpose.

This month we discuss the necessary tools and equipment for the casting, and next month we shall proceed step by step through the actual pouring. In the preparation of this article, I have had the cooperation of Betty Knox, science editor of the Amateur Astronomers Association of Pittsburgh.

The tools and equipment which must be assembled or made are listed below, and specifications for their construction follow.

1 molding board
1 rammer
2 molding boxes or flasks (cope and drag)
1 sandbox
1 sand sifter
4 riser patterns
1 trap pattern
1 pair of pouring tongs
1 slag remover
1 trowel
1 striking stick
1 furnace with blower
1 No. 7 crucible
2 fire bricks for safety place for furnace lid
1 small hammer
A few 1" wire brads
1 eye-dropper
1 salt shaker
1 water glass
5 pounds of white lake sand
1 bushel of brass foundry molding sand
Some scrap aluminum or brass
Patterns for casting

The **molding board,** made like a drawing board, is built from white pine. The dimensions are 1" x 18" x 18". Make it smooth with sandpaper and then shellac it. The **rammer** is also made of white pine. It is 8" long. The handle is 1" in diameter, 6" in length. The rammer end — which should be shellacked — is 2" in diameter and 2" in length.

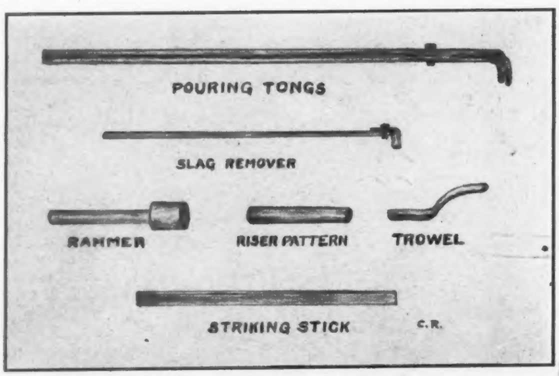
The flasks or **molding boxes** have open ends; the top flask is called the cope; the bottom flask, the drag. Both the cope and the drag are made from white pine. Dimensions are: 1" x 14" x 14". Eight pieces of material are required for the flasks. Be sure the end of each piece is sawed squarely. I recommend using brass screws to assemble the cope and the drag. Make certain they fit well, when you place one on top of the other. A good fit is essential. On two sides of the cope fit a piece of white pine 5/16" x 1¼" x 6" on center in a vertical position with screws. On two sides of the drag fit two pieces 5/16" x 1¼" x 4". Space the pieces apart, so the pieces on the cope slide into those on the drag. Use care and precision in making the cope and the drag, for this part of the job is important. Apply three coats of shellac on both the cope and the drag.

Make the **sandbox** for holding and mixing the molding sand from white pine boards. Dimensions are: 10" deep, 24" wide, 24" long. When assembling the box, make sure to fit the boards closely together. Use brass screws. Apply about four coats of shellac.

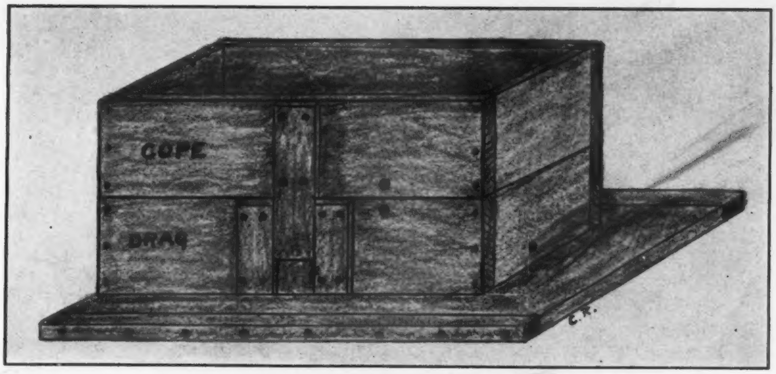
The **sand sifter** is made from four pieces of white pine 7/8" x 2" x 8". The ends of the pieces must be squarely cut and put together with wood screws to form an open-end box. A piece of bronze fly screen is attached to one end with copper tacks to form a sifter.

The **riser patterns** are turned from white pine. Make four patterns, each 5" long, 1" diameter on one end and tapered to 7/8" on the opposite end. Shellac them. The **trap pattern** is made from white pine. Make it 1" x 1" x 2". Shellac. (Note: I make my own shellac in small quantities as I need it, from wood alcohol and orange shellac.)

The **pouring tongs** are made from two lengths of round, hot rolled steel of low carbon content, ½" x 3' 6". Thirty-three inches from the ends of each rod, heat and flatten to provide enough width to drill a hole that will take a ¼" machine



Some of the implements required for the molding and casting operations are pictured here. They are all homemade.



The cope and drag on the molding board. All drawings are by Mr. Raible.

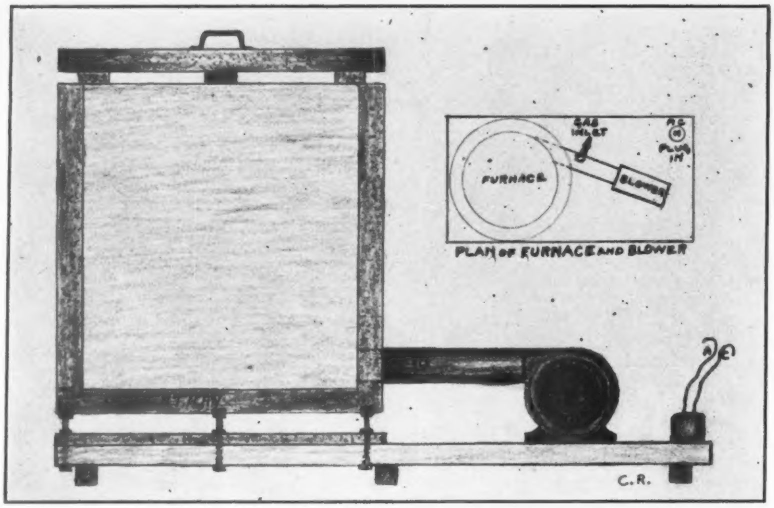
bolt, so that the two rods may be bolted together. From the holes to the ends of the rods, heat and draw to a taper to form the jaws. At a point 2" back from the drawn ends, bend at a right angle, to provide a means for grasping the top edge of the crucible when pouring.

Make the **slag remover** from a piece of round steel ¼" x 3'. Bend a piece of flat steel ⅛" x 1" x 3" at right angles. Attach it to the end of the round rod with an 8-32 steel machine screw and nut.

The **trowel** is used for making the "gates" or "gutters" between the pouring head, the trap, the pattern, and the risers. It is made by cutting a piece 5/8" wide and 2" long from a tin can. Curve it over a ½" diameter pipe. Attach it to [illegible] piece of metal to form a handle shaping it like a teaspoon handle.

The **striking stick** is made of a piece of straight strip steel, ⅛" x 1" x 18".

The **furnace** is prepared as follows: Start with a board 1" x 12" x 24". On one side of it attach three pieces of wood 1" x 1" x 12". Place one piece in the center of the board and the remaining pieces on each end. Now insulate one half of the opposite side of the board with ½" of asbestos. Make four holes in the bottom of a five-gallon paint can that will take four 5/16" x 3" machine bolts spaced 90° apart around the circumfer[illegible]. Next drill four holes in the insu[illegible]d part of the board to match holes in [illegible] can. Cut a 2" diameter hole in the [illegible] of the can 2" above the bottom. This [illegible] is for the gas and air inlet. The four [illegible]" x 3" bolts must have 2" of threads. [illegible] the bolts through the holes in the



The furnace in which the metal is melted. The inset shows the arrangement of the parts.

board and run the nuts down tight over the insulation. Next run four more nuts on the bolts and leave a space of 1" between the top of the insulation and the top nut. Now place the can on top of the bolts through the four holes. Run nuts on the ends of the bolts which protrude through the bottom of the can and tighten them.

Next you need a piece of tubing 2" diameter and 8" long. This tube can be made from thin sheet steel or a piece of brass tubing. Two inches from one end of the tube cut a hole large enough so that a 3/8" nipple may be inserted. Now you need a 3/8" elbow, a 3/8" x 2" nipple and two half 3/8" nuts equipped with 3/8" pipe threads. Screw one of the nuts all the way to the end of the nipple and insert the end of the nipple with the nut into the hole of the 2" x 8" tube. Now screw the other nut on the end of the nipple inside the tube. Pull it up tightly and put the elbow on. Be sure to have the elbow turned so the gas will enter the furnace. Mount the blower at an angle on the board, so that air and gas may blow into the furnace and create a spiral around the crucible. With your blower in its proper position, shove the 2" tube (nipple end) into the hole of the furnace and pull it back far enough for you to fit on the blower fitting. On the end of the 3/8" nipple place a brass hose connection.

Next mix equal parts of fire clay and asbestos cement thoroughly; then mix two thirds water and one third pure sodium silicate. Wet the first mixture with the latter and knead it into a dough. Wet just enough, so it doesn't stick to your hands. Place 1¼" of the mixture on the bottom of the inside of the can. Now insulate the inside wall of the can with 1¼" of the same mixture. Smooth it so there are no rough, raised, or depressed areas. On the top edge of the circumference of the can make three raised areas 90° apart, ¾" high by 1¼" x 2". This will serve as a resting place for the lid and as an exhaust port. Be sure to leave the hole into the furnace open, so the gas and air may enter properly. Cover the outside of the can with six plies of asbestos paper. Where the blower tube enters the hole on the outside of the furnace, use some of the asbestos and clay to fill in any cracks. It isn't necessary to insulate the gas and blower tube, for it is always kept cool by the blower.

The furnace lid is made from the paint-can lid. Take a piece of soft steel wire ⅛" diameter and 8" long. Form it into the shape of a handle, and fasten or weld its ends to the center of the lid. Insulate both sides of the lid 3/4" thick with the mixture used to insulate the inside of the furnace. Let the furnace dry for 24 hours before using. When lighting the furnace, always light the gas first, then start the blower and place the lid on top. You should have a No. 7 crucible loaded with melted aluminum and ready for pouring in 14 minutes.

(To be concluded)

C. RAIBLE
200 Rebecca Sq.
Millvale 9, Pa.

OBSERVER'S PAGE

Universal time is used unless otherwise noted.

OCCULTATION OF VENUS

A COMMUNICATION from Dr. E. W. Woolard, of the U. S. Naval Observatory in Washington, calls attention to an occultation of Venus very close to the sun on the morning of July 22nd. Conjunction with the moon occurs at 16:23 UT. It will be in the zenith at longitude 57° west, latitude 19°.7 north, at that moment above the horizon everywhere in the United States.

As the moon will be only 17 hours past new and approximately 8° east of the sun, the circumstances of the occultation were not computed at the Nautical Almanac Office. Computations have been made for standard stations **A** and **C** and for my local station in Rochester, and these indicate that the occultation will be generally observable throughout the United States. It is likely that the planet will not disappear at stations in the northwestern part of the country. Observers on the Atlantic Coast will be most favored, as the altitude of Venus at immersion will be about 50°.

Approximate times of immersion are: station **A**, 15:01; station **C**, 14:37. Because of proximity to the sun, the lunar crescent will doubtless be unobservable. Accordingly, position angles and emersion times have not been determined. If your telescope has setting circles, try to locate the planet (magnitude −3.4) at right ascension $8^h\ 40^m$, declination +19° 40′, at about 9:00 a.m. (EST) and watch for it to disappear behind an unseen lunar limb.

Early evening twilight on July 22nd will provide an excellent opportunity to locate Venus beneath the slender crescent of a day-old moon. Binoculars will be a great aid for this observation, at a time about as soon after superior conjunction with the sun as Venus can be detected after sunset. Mercury, a week past greatest elongation, should be easily observed some 16° farther east than Venus.

PAUL W. STEVENS

BIRD MIGRATION PROGRAM — OBSERVERS WANTED

In the spring of 1948, 200 astronomers and ornithologists, representing 30 localities on the North American continent, pooled their efforts to obtain counts of migrating birds passing before the disk of the moon. By means of mathematical procedures developed by Prof. W. A. Rense, department of physics and astronomy, Louisiana State University, these counts were used to obtain indices of the volume and direction of migration at different times, at different places, and under different circumstances. The method has been explained in two papers by Professor Rense ("Astronomy and Ornithology," **Popular Astronomy, 54**, 55-73; "Some Notes on the Astronomical Method of Studying Bird Migration," **Popular Astronomy, 58**, 287-294); and the surprising ornithological results achieved with it have been described in a recent study by George H. Lowery, Jr. ("A Quantitative Study of the Nocturnal Migration of Birds," University of Kansas **Publications**, Museum of Natural History, **3**, 2, 361).

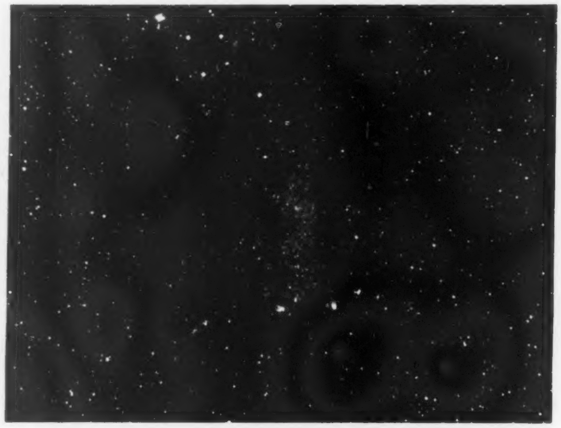
A second co-operative effort is being staged in the fall of 1952, when an attempt will be made to saturate the country with observers. Persons with access to a telescope have an opportunity to contribute tremendously to the solution of the many puzzling problems connected with the movement of birds at night. The observational procedure is a simple one. Details regarding both the method and other aspects of the problem may be secured by writing at once to Robert J. Newman, Museum of Zoology, Louisiana State University, Baton Rouge 3, La.

DEEP-SKY WONDERS

A YEAR AGO this column told of Barnard's nebula, an irregular galaxy belonging to our local group. It lies farther from us than the Magellanic Clouds but much closer than M31 in Andromeda. The material and chart are on page 256 of the August, 1951, issue, and an account of actual observing of this elusive object is in the October, 1951, issue, page 303. On the chart, the galaxy's position was indicated in the Beyer-Graff fashion by a small **x**, a satisfactory method for the usual object, but here we have a faint specimen about a third as large as the moon. We are afraid many amateurs failed because they were looking for a smaller object. Actually, at 120x the nebula fills most of the eyepiece field with a faint, yet certain illumination. Averted vision is, as always, absolutely necessary.

Data on the galaxy are: NGC 6822, $19^h 42^m.1$, $-14°\ 53'$ (1950), magnitude 11.0, $20' \times 10'$, type I. My first personal notation on this is dated August, 1943, when a flight in an Army plane to southern Florida with an overnight layover gave me opportunity to search low latitudes. I brought along a 6-inch rich-field and observed many objects too far south for my Wisconsin observing horizon. NGC 6822 was a most conspicuous object that night, a crystalline veil seemingly suspended between earth and the starry background. My low power of 20x made it difficult to recognize the neighboring planetary, NGC 6818, but the Barnard nebula was so evident that I wondered why the Herschels had missed it.

WALTER SCOTT HOUSTON



The field of the irregular galaxy known as Barnard's nebula, NGC 6822, in the constellation of Sagittarius. South is at the top. Mount Wilson Observatory photograph.

SKY-GAZERS EXCHANGE

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METEORS IN JULY

July begins the half of the year when meteors are most numerous and the best showers appear. The Delta Aquarid shower, observable the last 10 days of the month, is favored this year by the absence of the moon. This fine display comes to maximum on July 28th, with rates of 20 to 30 meteors per hour after midnight expected under good conditions. These meteors are slow, often yellow in color with many brighter ones leaving trains. Meteors from the Perseid shower first appear at this time after midnight and are generally fainter than the Delta Aquarids but very swift. E. O.

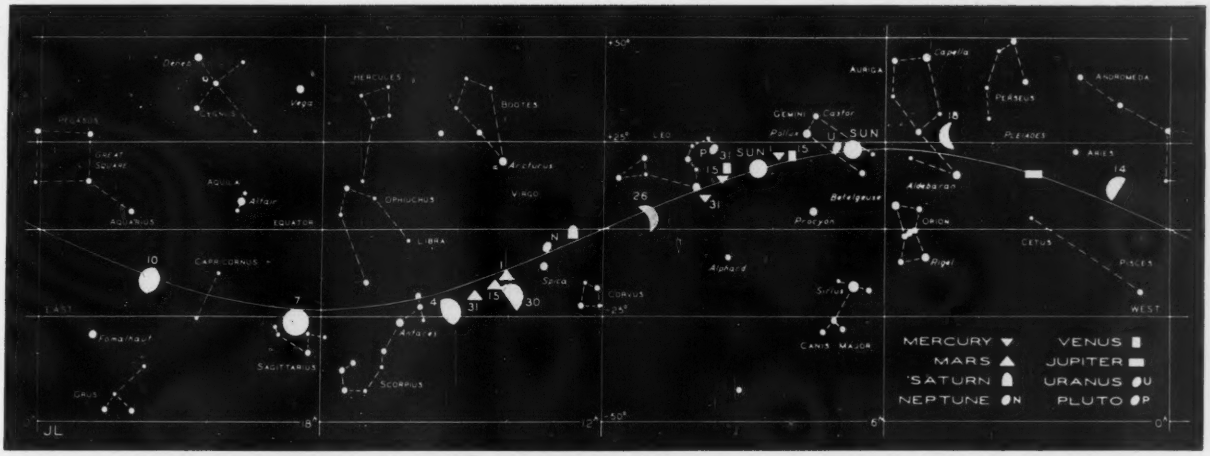
PHASES OF THE MOON

Full moon	July 7,	12:33
Last quarter	July 14,	3:42
New moon	July 21,	23:30
First quarter	July 30,	1:51
Full moon	August 5,	19:40

	July	Distance	Diameter
Perigee	8, 11^h	222,800 mi.	33′ 19″
Apogee	23, 8^h	252,500 mi.	29′ 24″
	August		
Perigee	5, 20^h	221,900 mi.	33′ 28″

UNIVERSAL TIME (UT)

TIMES used on the Observer's Page are Greenwich civil or Universal time, unless otherwise noted. This is 24-hour time, from midnight to midnight; times greater than 12:00 are p.m. Subtract the following hours to convert to standard times in the United States: EST, 5; CST, 6; MST, 7; PST, 8. If necessary, add 24 hours to the UT before subtracting, and the result is your standard time on the day preceding the Greenwich date shown. Add one hour for daylight-saving time.



THE SUN, MOON, AND PLANETS THIS MONTH

The sun, on the ecliptic, is shown for the beginning and end of the month. The moon's symbols give its phase roughly, with the date marked alongside. Each planet is located for the middle of the month and for other dates shown.

Mercury attains greatest elongation on July 15th, 26° 40′ east of the sun. At that time the planet will set one hour after the sun and be at +0.6 magnitude. However, the preceding two weeks will be more favorable for viewing Mercury as it sets later and is somewhat brighter.

Venus remains too close to the sun for observation this month.

Mars moves eastward from Virgo to Libra, remaining a conspicuous object in the evening sky. Its magnitude decreases to −0.2 in mid-month, when the ruddy planet sets at midnight. Mars presents a disk 11″ in diameter on the 15th.

Jupiter rises before midnight in late July, outshining all stars and planets at magnitude −1.9. Moving eastward in Aries, Jupiter again will be a fine object for the small telescope, with an equatorial diameter of 37″ on the 15th.

Saturn, an early evening object moving eastward in the western sky, passes Gamma Virginis once again. The ring system will be inclined 7°.2 on the 15th, with the northern face in view.

Uranus will be in conjunction with the sun on July 6th, hence invisible.

Neptune, located about 8° east of Saturn, can be found with binoculars and the aid of the chart in the February issue. Eastern quadrature is attained on July 11th; the planet remains at 8th magnitude.

E. O.

SUNSPOT NUMBERS

April 1, 25, 28; **2,** 19, 16; **3,** 25, 21; **4,** 28, 26; **5,** 33, 37; **6,** 27, 33; **7,** 35, 37; **8,** 29, 40; **9,** 31, 32; **10,** 30, 30; **11,** 35, 46; **12,** 21, 28; **13,** 19, 22; **14,** 10, 19; **15,** 2, 7; **16,** 5, 8; **17,** 11, 7; **18,** 20, 17; **19,** 36, 33; **20,** 44, 53; **21,** 55, 62; **22,** 50, 50; **23,** 31, 38; **24,** 26, 26; **25,** 23, 15; **26,** 23, 26; **27,** 21, 16; **28,** 25, 17; **29,** 40, 32; **30,** 40, 42. Means for April: 27.3 American; 28.8 Zurich.

Daily values of the observed mean relative sunspot numbers for April are given above. The first are the American numbers computed by Neal J. Heines from Solar Division observations; the second are the Zurich Observatory numbers.

PREDICTIONS OF BRIGHT ASTEROID POSITIONS

Metis, 9, 9.3. June 27, 20:49.1 −24-17. July 7, 20:42.5 −25-12; 17, 20:33.7 −26-08; 27, 20:23.5 −26-59. Aug. 6, 20:13.1 −27-41; 16, 20:03.8 −28-08.

Antigone, 129, 9.4. July 7, 20:41.4 −11-57; 17, 20:34.6 −13-13; 27, 20:26.7 −14-37. Aug. 6, 20:18.9 −16-03; 16, 20:12.1 −17-25; 26, 20:07.3 −18-38.

Hera, 103, 9.7. July 7, 21:03.6 −14-39; 17, 20:57.7 −15-25; 27, 20:50.0 −16-20. Aug. 6, 20:41.6 −17-18; 16, 20:33.7 −18-14; 26, 20:27.4 −19-03.

Juno, 3, 8.6. July 17, 21:22.1 −2-10; 27, 21:15.4 −2-54. Aug. 6, 21:07.4 −3-58; 16, 20:58.9 −5-18; 26, 20:51.0 −6-46. Sept. 5, 20:44.6 −8-18.

Prokne, 194, 8.9. July 27, 22:10.6 +1-31. Aug. 6, 22:07.5 −0-40; 16, 22:02.5 −3-26; 26, 21:56.9 −6-31. Sept. 5, 21:51.9 −9-38; 15, 21:48.8 −12-30.

After the asteroid's name are its number and the magnitude expected at opposition. At 10-day intervals are given its right ascension and declination (1952.0) for 0^h^ Universal time. In each case the motion of the asteroid is retrograde. Data supplied by the IAU Minor Planet Center at the University of Cincinnati Observatory.

VARIABLE STAR MAXIMA

July 2, R Reticuli, 7.7, 0432**63**; 2, S Carinae, 5.7, 1006**61**; 4, V Cassiopeiae, 7.9, 230759; 9, R Leonis, 5.9, 094211; 16, R Draconis, 7.6, 163266; 16, RU Sagittarii, 7.2, 1951**42**; 26, T Cephei, 5.8, 210868.

These predictions of variable star maxima are by the AAVSO. Only stars are included whose mean maximum magnitudes are brighter than magnitude 8.0. Some, but not all of them, are nearly as bright as maximum two or three weeks before and after the dates for maximum. The data given include, in order, the day of the month near which the maximum should occur, the star name, the predicted magnitude, and the star designation number, which gives the rough right ascension (first four figures) and declination (bold face if southern).

MINIMA OF ALGOL

July 1, 15:31; 4, 12:19; 7, 9:08; 10, 5:57; 13, 2:45; 15, 23:34; 18, 20:23; 21, 17:11; 24, 14:00; 27, 10:48; 30, 7:37. August 2, 4:25; 5, 1:14.

These predictions are geocentric (corrected for the equation of light), based on observations made in 1947. See Sky and Telescope, Vol. VII, page 260, August, 1948, for further explanation.

The sky as seen from latitudes 20° to 40° south, at 9 p.m. and 8 p.m., local time, on the 7th and 23rd of October, respectively.

SOUTHERN STARS

CONSTELLATIONS that are high in Southern Hemisphere October evening skies include Piscis Austrinus, Grus, Microscopium, Capricornus, and Aquarius. Somewhat farther away from the zenith at chart time are Sculptor, Phoenix, Tucana, Indus, and Pavo. Many of these groups are made up mostly of faint stars, which may be more easily identified when they are high in the sky.

The 1st-magnitude star Fomalhaut, in the Southern Fish, is at right ascension 23^h, close to declination —30°. Along this parallel, there are no other stars brighter than the 4th magnitude all the way from Zeta (ζ) Sagittarii, at 19^h, eastward to about 5^h. Microscopium, Piscis Austrinus (except for Fomalhaut), Sculptor, and Fornax are faint constellations lying along this strip of sky.

In Grus, which has the long cranelike shape for which it is named, there are several interesting pairs of stars, particularly Delta (δ) and nearby Mu. Between Beta (β) and Epsilon (ϵ), there are three close stars (fainter than the chart limiting magnitude).

Grus also contains two 2nd-magnitude stars, of which Alpha (α) is blue-white, of spectral type **B**, whereas Beta is red, of type **M**.

STARS FOR JULY

The sky as seen from latitudes 30° to 50° north, at 9 p.m. and 8 p.m., local time, on the 7th and 23rd of July, respectively; also, at 7 p.m. and 6 p.m. on August 7th and 23rd. For other times, add or subtract ½ hour per week. When facing north, hold "North" at the bottom; turn the chart correspondingly for other directions. The projection (stereographic) shows celestial co-ordinates as circles.